CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

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CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

8.1 INTRODUCTION

This chapter describes the Department of Energy (DOE)'s methodology for analyzing the economic impacts of possible energy conservation standards on individual consumers. The effect of energy conservation standards on individual consumers includes a change in operating expense (usually decreased) and a change in purchase price (usually increased). This chapter describes three metrics DOE used to determine the effect of energy conservation standards on individual consumers:

- **Life-cycle cost** (LCC) is the total consumer expense over the life of an appliance, including purchase expense and operating costs (including energy expenditures). DOE discounts future operating costs to the time of purchase, and sums them over the lifetime of the product.

- **Payback period** (PBP) measures the amount of time it takes consumers to recover the estimated higher purchase price of more energy efficient products through lower operating costs.

- **Rebuttable payback period** is a special case of the PBP. While the LCC and PBP are estimated over a range of inputs reflecting actual conditions, the rebuttable payback period is based on laboratory conditions, specifically DOE test procedure inputs.

Results for the LCC and PBP analyses are presented in section 8.11, and the rebuttable PBP is discussed in section 8.12. Key variables and calculations are presented for each metric. DOE performed the calculations discussed here using a series of Microsoft Excel spreadsheets which are accessible on the Internet at (http://www.eere.energy.gov/buildings/appliance_standards/). Details and instructions for using the spreadsheets are discussed in appendix 8-H, User Instructions for the LCC Analysis Spreadsheet.

8.1.1 General Approach for LCC and PBP Analyses

Life-cycle cost is the total consumer expense over the life of an appliance, including purchase expense and operating costs (including energy expenditures). DOE discounts future operating costs to the time of purchase, and sums them over the lifetime of the product. DOE defines LCC by the following equation:

$$LCC = IC + \sum_{t=1}^{N} \frac{OC_t}{(1+r)^t}$$

Where:

LCC = Life-cycle cost in dollars,
IC = Total installed cost in dollars,

$\sum$ = Sum over the lifetime, from year 1 to year N,
N = Lifetime of appliance in years,
OC = Operating cost in dollars,
r = Discount rate, and
t = Year for which operating cost is being determined.

The PBP is the amount of time it takes the consumer to recover the estimated higher purchase expense of more energy efficient products as a result of lower operating costs. Numerically, the PBP is the ratio of the increase in purchase expense (i.e., from a less energy efficient design to a more energy efficient design) to the decrease in annual operating expenditures. This type of calculation is known as a "simple" payback period, because it does not take into account changes in operating expense over time or the time value of money; (i.e., the calculation is done at an effective discount rate of zero percent).

The equation for PBP is:

$$PBP = \frac{\Delta IP}{\Delta OC}$$

Where:

ΔIP = Difference in the total installed price between the more energy efficient design and the baseline design, and
ΔOC = difference in annual operating expenses.

Payback periods are expressed in years. Payback periods greater than the life of the product indicate that the increased total installed cost is not recovered with the reduced operating expenses.

Recognizing that several inputs used to determine consumer LCC and PBP are either variable or uncertain, DOE conducted the LCC and PBP analyses by modeling both the uncertainty and variability in the inputs using Monte Carlo simulation and probability distributions. A detailed explanation of the use of probability distributions is included in this chapter. DOE developed LCC and PBP spreadsheet models incorporating both Monte Carlo simulation and probability distributions by using Microsoft Excel spreadsheets combined with Crystal Ball (a commercially available add-in program).

In addition to characterizing several inputs of the analyses with probability distributions, DOE developed a sample of individual households that use each of the appliances. By developing household samples, DOE was able to perform the LCC and PBP calculations for each household to account for the variability in energy consumption and/or energy price associated with each household. As described in chapter 7, Energy Use Characterization, DOE used the DOE Energy Information Administration (EIA)'s 2005 Residential Energy Consumption Survey (RECS) to develop household samples for each of the three heating products.[1]

By using RECS, DOE was able to assign a specific annual energy use and energy price to each household in the sample. Due to the large sample of households considered in the LCC and PBP analyses, the range of annual energy use within each product class considered is quite large. Thus, the variability of annual energy use and energy prices across all households contributes to the range of LCCs and PBPs calculated for any particular energy conservation standard level.

DOE displays the LCC and PBP results as distributions of impacts compared to the base case. Results are presented at the end of this chapter and are based on 10,000 samples per Monte Carlo simulation run.

8.1.2 Overview of LCC and PBP Inputs

DOE categorizes inputs to the LCC and PBP analyses as follows: (1) inputs for establishing the purchase expense, otherwise known as the total installed price, and (2) inputs for calculating the operating cost.

The primary inputs for establishing the total installed price are:

- *Baseline manufacturer cost*: The costs incurred by the manufacturer to produce products meeting existing minimum energy conservation standards.

- *Standard-level manufacturer cost increases*: The change in manufacturer cost associated with producing products to meet a particular energy conservation standard level.

- *Markups and sales tax*: The markups and sales tax associated with converting the manufacturer cost to a consumer product cost.

- *Installation cost*: The cost to the consumer of installing the product. The installation cost represents all costs required to install the product other than the marked-up consumer product price. The installation cost includes labor, overhead, and any miscellaneous materials and parts. Thus, the total installed price equals the consumer product price plus the installation cost.

The primary inputs for calculating the operating cost are:

- *Energy consumption*: The energy consumption is the site energy use associated with operating the product.

- *Energy efficiency*: The product energy efficiency dictates the product energy consumption associated with standard-level products (i.e., products with energy efficiencies greater than baseline products).

- *Energy prices*: Energy prices are the prices paid by consumers for energy (i.e., electricity, gas, or oil). DOE determined current energy prices based on data from the Energy Information Administration (EIA).

- *Energy price trends*: DOE used the EIA *Annual Energy Outlook 2010* (*AEO2010*) to forecast energy prices into the future.

- *Repair and maintenance costs*: Repair costs are associated with repairing or replacing components that have failed. Maintenance costs are associated with maintaining the operation of the product.

- *Lifetime*: The age at which the product is retired from service.

- *Discount rate*: The rate at which DOE discounted future expenditures to establish their present value.

The data inputs to PBP are the total installed price of the product to the consumer for each energy efficiency level and the annual (first year) operating expenditures for each energy conservation standard level. The inputs to the total installed price are the product cost and the installation cost. The inputs to the operating costs are the annual energy cost, the annual repair cost, and the annual maintenance cost. The PBP uses the same inputs as the LCC analysis, except that energy price trends and discount rates are not required. Since the PBP is a "simple" payback, the required energy price is only for the year in which a new energy conservation standard is to take effect. The energy price DOE used in the PBP calculation was the price projected for that year. Discount rates are also not required for the simple PBP calculation.

Figure 8.1.1 graphically depicts the relationships between the installed cost and operating cost inputs for the calculation of the LCC and PBP. In the figure below, the yellow boxes indicate the inputs, the green boxes indicate intermediate outputs, and the blue boxes indicate the final outputs (the LCC and PBP).

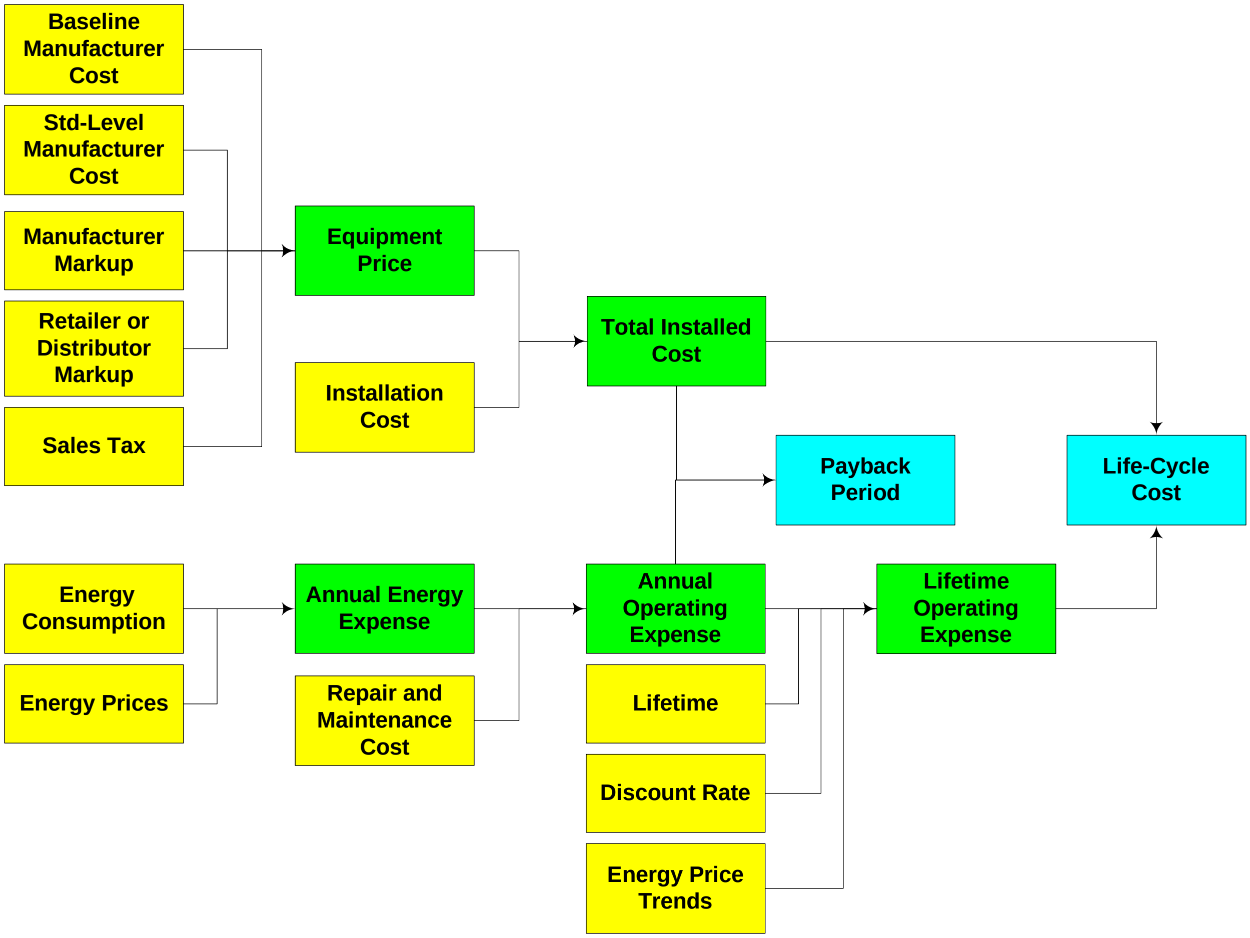

Figure 8.1.1 Flow Diagram of Inputs for the Determination of LCC and PBP

Table 8.1.1, Table 8.1.2, and Table 8.1.3 summarize the input values that DOE used to calculate the LCC and PBP for the three types of heating products. Each table summarizes the total installed price inputs and the operating cost inputs including the lifetime, discount rate, and energy price trends. DOE characterized all of the total cost inputs with single-point values, but characterized several of the operating cost inputs with probability distributions that capture the input's uncertainty and/or variability. For those inputs characterized with probability distributions, the values provided in the following tables are the average or typical values. Also listed in the following tables is the chapter of the technical support document (TSD) where more detailed information on the inputs can be found.

Table 8.1.1 Water Heaters: LCC and PBP Input Summary

Input	Product Class	Average or Typical Value	Characterization	TSD Chapter Reference
Total Installed Price Inputs				
Baseline Manufacturer Cost* (2009$)	Gas-fired storage-type	40 gal = $179 (+$18) 40 gal low-NOx = $273 (+$18)	Single-Point Value	5
	Electric storage-type	50 gal = $131 (+$20)		5
	Oil-fired storage-type	32 gal = $599 (+$16)		5
	Gas-fired instantaneous	199 kBtu/h = $308		5
Standard-Level Manufacturer Cost Increase* (2009$)	Gas-fired storage-type (40 gal)	0.62 EF = $8 (+$2) 0.63 EF = $16 (+$8) 0.64 EF = $142 (+$18) 0.65 EF = $150 (+$22) 0.67 EF = $158 (+$34) 0.77 EF = $299 (+$34)	Single-Point Value	5
	Electric storage-type (50 gal)	0.91 EF = $6 (+$1) 0.92 EF = $10 (+$1) 0.93 EF = $14 (+$1) 0.94 EF = $22 (+$7) 0.95 EF = $39 (+$36) 2.00 EF = $425 (+$44) 2.35 EF = $501 (+$44)	Single-Point Value	5
	Oil-fired storage-type (32 gal)	0.54 EF = $7 (+$1) 0.56 EF = $14 (+$2) 0.58 EF = $26 (+$9) 0.60 EF = $21 (+$2) 0.62 EF = $34 (+$9) 0.66 EF = $118 (+$9) 0.68 EF = $123	Single-Point Value	5
	Gas-fired instantaneous (199 kBtu/h)	0.69 EF = $15 0.78 EF = $44 0.80 EF = $154 0.82 EF = $193 0.84 EF = $488 0.85 EF = $540 0.92 EF = $620 0.95 EF = $724	Single-Point Value	5
Manufacturer Markup	Gas-fired storage-type	1.31	Single-Point Value	6
	Electric storage-type	1.28		6
	Oil-fired storage-type	1.30		6
	Gas-fired instantaneous	1.45		6
Retailer Markup	All	Baseline = 1.45 Incremental = 1.15	Single-Point Value	6
Distributor Markup	Gas-fired, Oil-fired storage, Gas-fired	Baseline = 1.35 Incremental = 1.11	Single-Point Value	6

	instantaneous			
	Electric Storage	Baseline = 1.28 Incremental = 1.10	Single-Point Value	6
Contractor Markup	All	1.10	Single-Point Value	6
Builder Markup	All	Baseline = 1.31 Incremental = 1.26	Single-Point Value	6
Sales Tax	Gas-fired storage-type	1.075	Variability based on region	6
	Electric storage-type	1.071		6
	Oil-fired storage-type	1.070		6
	Gas-fired instantaneous	1.075		6
Installation Cost (baseline)	Gas-fired storage-type	$630	Variability determined from household sample.	8
	Electric storage-type	$288		8
	Oil-fired storage-type	$646		8
	Gas-fired instantaneous	$1,045		8
Operating Cost Inputs				
Annual Energy Use (baseline)**	Gas-fired storage-type	Gas = 16.5 MMBtu	Variability determined from household sample.	7
	Electric storage-type	Elec = 2,604 kWh		7
	Oil-fired storage-type	Oil = 21.6 MMBtu Elec = 61 kWh		7
	Gas-fired instantaneous	Gas = 16.7 MMBtu		7
Forecasted Energy Prices in 2015 (2009$)	Gas-fired storage-type	Elec = 11.00 ¢/kWh Gas = 12.99 $/MMBtu LPG = 28.46 $/MMBtu	Variability based on region.	8
	Electric storage-type	Elec = 10.34 ¢/kWh		
	Oil-fired storage-type	Elec = 17.39 ¢/kWh Oil = 30.08 $/MMBtu		
	Gas-fired instantaneous	Elec = 11.15 ¢/kWh Gas = 13.02 $/MMBtu LPG = 28.24 $/MMBtu		
Repair and Maintenance Costs (baseline)	Gas-fired storage-type	Repair = $22 Maintenance = $10	Repair-variability based on product failure. Maintenance - Single-Point Value	8
	Electric storage-type	Repair = $20 Maintenance = $2		8
	Oil-fired storage-type	Repair = $0 Maintenance = $157		8
	Gas-fired instantaneous	Repair = $46 Maintenance = $61		8
Lifetime	Gas-fired storage-type	13 years	Weibull distribution = 6 to 20 years	8
	Electric storage-type	13 years	Weibull distribution = 6 to 20 years	8

	Oil-fired storage-type	13 years	Weibull distribution = 6 to 20 years	8
	Gas-fired instantaneous	20 years	Weibull distribution = 8 to 30 years	8
Discount Rate	All	Replacement purchases = 4.8% New home purchases = 3.0%	Custom distribution	8
Energy Price Trend	All	AEO2010 Reference Case	Two sensitivities: High & Low Growth Cases	8

* Values within parenthesis refer to shipping cost.
** Annual use provided for baseline product only. Annual use decreases with increased product energy efficiency.

Table 8.1.2 Direct Heating Equipment: LCC and PBP Input Summary

Input	Product Class	Average or Typical Value	Characterization	TSD Chapter Reference
Total Installed Price Inputs				
Baseline Manufacturer Cost (2009$)	Gas Wall Fan DHE	74% AFUE = $364	Single-Point Value	5
	Gas Wall Gravity DHE	64% AFUE = $214	Single-Point Value	5
	Gas Floor DHE	57% AFUE = $370	Single-Point Value	5
	Gas Room DHE	64% AFUE = $234	Single-Point Value	5
	Gas Hearth DHE	64% AFUE = $372	Single-Point Value	5
Standard-Level Manufacturer Cost Increase	Gas Wall Fan DHE	75% AFUE = $26 76% AFUE = $37 77% AFUE = $58 80% AFUE = $118	Single-Point Value	5
	Gas Wall Gravity DHE	66% AFUE = $28 68% AFUE = $45 69% AFUE = $81 70% AFUE = $142	Single-Point Value	5
	Gas Floor DHE	58% AFUE = $25	Single-Point Value	5
	Gas Room DHE	65% AFUE = $16 66% AFUE = $31 67% AFUE = $38 68% AFUE = $48 83% AFUE = $186	Single-Point Value	5
	Gas Hearth DHE	67% AFUE = -$2 72% AFUE = $178 93% AFUE = $546	Single-Point Value	5
Manufacturer Markup	All	1.35	Single-Point Value	6
Distributor Markup	All	Baseline = 1.35 Incremental = 1.11	Single-Point Value	6

Contractor Markup	All	Baseline = 1.32 Incremental = 1.32	Single-Point Value	6
Builder Markup	All	Baseline = 1.31 Incremental = 1.26	Single-Point Value	6
Sales Tax	All	1.074	Single-Point Value	6
Installation Cost (baseline)	Gas Wall Fan DHE	$861	Single-Point Value	8
	Gas Wall Gravity DHE	$861		
	Gas Floor DHE	$1,223		
	Gas Room DHE	$585		
	Gas Hearth DHE	$617		
Operating Cost Inputs				
Annual Gas Usage*	Gas Wall Fan DHE	29.9 MMBtu	Variability determined from household sample.	7
	Gas Wall Gravity DHE	29.9 MMBtu		
	Gas Floor DHE	30.8 MMBtu		
	Gas Room DHE (LPG)	27.5 MMBtu		
	Gas Hearth DHE	16.6 MMBtu		
Annual Electric Usage*	Gas Fan DHE	38.6 kWh	Variability determined from household sample.	7
	Gas Wall Gravity	0 kWh		
	Gas Floor DHE	0 kWh		
	Gas Room DHE	0 kWh		
	Gas Hearth DHE	0 kWh		
Forecasted Energy Prices in 2013 (2009$)	Gas Fan DHE	Elec = 11.54 ¢/kWh Gas = 12.79 $/MMBtu LPG = 26.56 $/MMBtu	Variability based on region	8
	Gas Wall Gravity	Elec = 11.54 ¢/kWh Gas = 12.79 $/MMBtu LPG = 26.56 $/MMBtu		
	Gas Floor DHE	Elec = 11.59 ¢/kWh Gas = 12.78 $/MMBtu LPG = 27.46 $/MMBtu		
	Gas Room DHE	Elec = 10.41 ¢/kWh Gas = 13.56 $/MMBtu LPG = 25.29 $/MMBtu		
	Gas Hearth DHE	Elec = 10.43 ¢/kWh Gas = 13.42 $/MMBtu LPG = 26.79 $/MMBtu		
Repair and Maintenance Costs (baseline, average)	Gas Wall Fan DHE	Repair =$105 Maintenance = $47	Repair-variability based on product failure Maintenance - Single-Point Value	8
	Gas Wall Gravity DHE	Repair =$43 Maintenance = $47		
	Gas Floor DHE	Repair =$44 Maintenance = $48		

	Gas Room DHE	Repair =$37 Maintenance = $40		
	Gas Hearth DHE	Repair =$39 Maintenance = $43		
Lifetime	All	15 years	Weibull distribution = 10 to 20 years	8
Discount Rate	All	Replacement purchases = 4.8% New home purchases = 3.0%	Custom distribution	8
Energy Price Trend	All	AEO2010 Reference Case	Two sensitivities: High & Low Growth Cases	8

* Annual use provided for baseline product only. Annual consumption decreases with increased product energy efficiency.

Table 8.1.3 Gas-Fired Pool Heaters: LCC and PBP Input Summary

Input	Average or Typical Value	Characterization	TSD Chapter Reference
Total Installed Price Inputs			
Baseline Manufacturer Cost	78% Et (pilot) = $568 78% Et (elect. Ignt.) = $587	Single-Point Value	5
Standard-Level Manufacturer Cost Increase	79% Et (pilot) = $11 79% Et (electr. Ignt.) = $11 81% Et (pilot) = $25 81% Et (electr. Ignt.) = $25 82% Et (pilot) = $58 82% Et (electr. Ignt.) = $58 83% Et (electr. Ignt.) = $129 84% Et (electr. Ignt.) = $191 86% Et (electr. Ignt.) = $444 90% Et (electr. Ignt.) = $941 95% Et (electr. Ignt.) = $1,082	Single-Point Value	5
Manufacturer Markup	Baseline = 1.30 Incremental = 1.30	Single-Point Value	6
Distributor Markup	Baseline = 1.35 Incremental = 1.11	Single-Point Value	6
Contractor Markup	Baseline = 1.10 Incremental = 1.10	Single-Point Value	6
Builder Markup	Baseline = 1.31 Incremental = 1.26	Single-Point Value	6
Sales Tax	1.075	Variability based on region	6
Installation Cost (baseline)	$1,936	Variability based on household sample.	8
Operating Cost Inputs			
Annual Gas Usage	Baseline = 34.1 MMBtu	Variability based on usage	7
Annual Electricity Usage	Baseline = 2.3 kWh	Variability based on usage	7
Forecasted Energy Prices in 2013 (2009$)	Elec = 11.64 ¢/kWh Gas = 13.43 $/MMBtu LPG = 29.27 $/MMBtu	Variability based on region	8
Repair and Maintenance Costs (baseline)	Repair = $23 Maintenance = $70	Repair-variability based on product failure Maintenance - Single-Point Value	8
Lifetime	10 years	Weibull distribution = 3 to 20 years	8
Discount Rate	Replacement purchases = 4.8% New home purchases = 3.0%	Custom distribution	8
Energy Price Trend	AEO2010 Reference Case	Sensitivities: High & Low Growth Cases	8

8.1.3 New Construction and Replacement Fractions of Heating Product Shipments

The LCC and PBP analyses use separate values for new construction applications and replacement applications for some variables, as the type of application influences these variables. Such variables include markups, installation costs, and discount rates. The derivation of the appropriate values in each case for new construction applications and replacement applications is given in chapter 6 for markups, and in this chapter for installation costs and discount rates.

The analysis requires assignment of the values for new construction applications and replacement applications to specific households in the household sample for each heating product. For water heaters and pool heaters, DOE based the assignment on the estimated fractions of shipments going to new construction and replacement applications in the effective year from the shipments analysis (see chapter 9). For pool heaters, DOE assigned “first-time owners” to the new construction cohort for installation costs because the installation is similar to new construction. It assigned them to the replacement cohort for discount rates since a first-time owner purchase is similar to that of a replacement purchase.

For direct heating equipment, the shipments analysis does not separately estimate shipments for these two market segments. DOE estimated that all gas floor DHE shipments are replacements and that 90 percent of all other direct heating equipment shipments are replacements. For gas hearth DHE, DOE estimated that half of the shipments are for new construction applications and that half are for replacement applications.

Table 8.1.4 shows the fractions used in the analysis for each heating product.

Table 8.1.4 Fraction of Shipments In New Construction and Replacement Applications

Heating Product	Share of Replacement Applications (%)	Share of New Construction Applications (%)
Water Heaters		
Gas-Fired Storage	85	15
Electric Storage	80	20
Oil-Fired Storage	85	15
Gas-Fired Instantaneous	70	30
DHE		
Gas Wall Fan	90	10
Gas Wall Gravity	90	10
Gas Floor	100	0
Gas Room	90	10
Gas Hearth	50	50
Pool Heaters	67*	33*

* The assignment of “first-time owners” varies; see explanation in text.

8.2 TOTAL INSTALLED PRICE INPUTS

DOE defines the total installed price using the following equation:

$$IP = CPC + INST$$

Where:

IP = Total installed cost, and
CPP = Consumer product price (i.e., consumer price for the product only), and
INST = Cost to the consumer to install products.

The product price is based on how the consumer purchases the product. As discussed in chapter 6, Markups to Determine Product Price, DOE defined markups and sales taxes for converting manufacturing costs into the consumer product price.

Table 8.2.1 summarizes the inputs for the determination of total installed price.

Table 8.2.1 Inputs for Total Installed Price

Baseline Manufacturer Cost
Standard-Level Manufacturer Cost
Distribution Chain Markups
Sales Tax (replacement applications)
Installation Cost

The *baseline manufacturer cost* is the cost incurred by the manufacturer to produce products meeting existing minimum energy conservation standards. *Standard-level manufacturer cost increases* are the change in manufacturer cost associated with producing products at an energy conservation standard level. *Markups and sales tax* convert the manufacturer cost to a consumer product price. The *installation cost* is the cost to the consumer of installing the product and represents all costs required to install the product other than the marked-up consumer product price. The installation cost includes labor, overhead, and any miscellaneous materials and parts.

DOE calculated the total installed price for baseline products based on the following equation:

$$\begin{aligned} IP_{BASE} &= CPP_{BASE} + INST_{BASE} \\ &= COST_{MFG} \times MU_{OVERALL\_BASE} + INST_{BASE} \end{aligned}$$

Where:

IP_{BASE} = Baseline total installed price,
CPP_{BASE} = Consumer product price for baseline models,
$INST_{BASE}$ = Baseline installation cost,
$COST_{MFG}$ = Manufacturer cost for baseline models, and
$MU_{OVERALL\_BASE}$ = Baseline overall markup (product of manufacturer markup, other markups, and (for replacement applications) sales tax).

DOE calculated the total installed price for standard-level products based on the following equation:

$$
\begin{aligned}
IP_{STD} &= CPP_{STD} + INST_{STD} \\
&= \left(CPP_{BASE} + \Delta CPP_{STD}\right) + \left(INST_{BASE} + \Delta INST_{STD}\right) \\
&= \left(CPP_{BASE} + INST_{BASE}\right) + \left(\Delta CPP_{STD} + \Delta INST_{STD}\right) \\
&= IP_{BASE} + \left(\Delta COST_{MFG} \times MU_{OVERALL\_INCR} + \Delta INST_{STD}\right)
\end{aligned}
$$

Where:

IC_{STD} =	Standard-level total installed price,
CPP_{STD} =	Consumer product price for standard-level models,
$INST_{STD}$ =	Standard-level installation cost,
CPP_{BASE} =	Consumer product price for baseline models,
ΔCPP_{STD} =	Change in product price for standard-level models,
$INST_{BASE}$ =	Baseline installation cost,
$\Delta INST_{STD}$ =	Change in installation cost for standard-level models,
IP_{BASE} =	Baseline total installed price,
$\Delta COST_{MFG}$ =	Change in manufacturer cost for standard-level models, and
$MU_{OVERALL\_INCR}$ =	Incremental overall markup (product of manufacturer markup, other markups, and (for replacement applications) sales tax).

The remainder of this section provides information about each of the above input variables that DOE used to calculate the total installed price for the three heating products.

8.2.2 Water Heaters

8.2.2.1 Baseline Manufacturer Cost

DOE developed the baseline manufacturer costs for water heaters as described in chapter 5, Engineering Analysis. The baseline manufacturer costs are shown in Table 8.2.2.

DOE assumed that the South Coast Air Quality Management District, Bay Area Air Quality Management District, Yolo-Solano Air Quality Management District, and the San Joaquin Valley Air Pollution Control District would be the locations where ultra low NOx gas-fired water heaters would be required by 2015. DOE estimated that this would represent 50 percent of shipments to California or 8.7 percent of shipments nationally.

Table 8.2.2 Water Heaters: Baseline Manufacturer Costs

Product Class	Rated Volume *(gal)*	Energy Factor	Manufacturer Cost *(2009$)*
Gas-Fired Storage	30	0.61	165
	40	0.59	179
	50	0.58	191
	65	0.54	220
	75	0.53	237
Gas-Fired Storage, low NOx	30	0.61	257
	40	0.59	273
	50	0.58	285
	65	0.54	313
	75	0.53	333
Electric Storage	30	0.93	109
	40	0.92	122
	50	0.90	131
	65	0.88	140
	80	0.86	160
	119	0.81	216
Oil-Fired Storage	32	0.53	599
	50	0.50	662
Gas-Fired Instantaneous	0*	0.62	308

* 199 kBtu/h rated input.

8.2.2.2 Standard-Level Manufacturer Cost Increases

DOE developed manufacturer cost increases associated with increases in product energy efficiency levels as described in chapter 5, Engineering Analysis. Table 8.2.3 through Table 8.2.7 present the standard-level manufacturer cost increases for the four product classes.

Table 8.2.3 Gas-Fired Storage Water Heaters: Standard-Level Manufacturer Cost Increases

Energy Efficiency Level	Manufacturer Cost Increase *(2009$)*				
	30 gal	**40 gal**	**50 gal**	**65 gal**	**75 gal**
1	$7.00	$8.00	$9.00	$10.00	$11.00
2	$15.00	$16.00	$18.00	$21.00	$22.00
3	$141.00	$142.00	$142.00	$144.00	$145.00
4	$148.00	$150.00	$151.00	$155.00	$156.00
5	$156.00	$158.00	$160.00	$166.00	$168.00
6	$289.00	$299.00	$300.00	$317.00	$328.00

Table 8.2.4 Gas-Fired Storage Water Heaters: Standard-Level Manufacturer Cost Increases for Low-NOx Models

Energy Efficiency Level	Manufacturer Cost Increase *(2009$)*				
	30 gal	**40 gal**	**50 gal**	**65 gal**	**75 gal**
1	$16.00	$17.00	$18.00	$23.00	$23.00
2	$137.00	$137.00	$137.00	$140.00	$141.00
3	$145.00	$145.00	$146.00	$150.00	$150.00
4	$152.00	$153.00	$155.00	$161.00	$163.00
5	$286.00	$294.00	$298.00	$318.00	$326.00
6	$286.00	$294.00	$298.00	$318.00	$326.00

Table 8.2.5 Electric Storage Water Heaters: Standard-Level Manufacturer Cost Increases

Energy Efficiency Level	Manufacturer Cost Increase *(2009$)*					
	30 gal	**40 gal**	**50 gal**	**65 gal**	**80 gal**	**119 gal**
1	$6.00	$6.00	$6.00	$8.00	$8.00	$10.00
2	$10.00	$11.00	$10.00	$13.00	$15.00	$18.00
3	$12.00	$13.00	$14.00	$16.00	$18.00	$22.00
4	$18.00	$21.00	$22.00	$26.00	$28.00	$33.00
5	$33.00	$37.00	$39.00	$45.00	$48.00	$57.00
6	$421.00	$424.00	$425.00	$429.00	$432.00	$439.00
7	$484.00	$499.00	$501.00	$513.00	$523.00	$529.00

Table 8.2.6 Oil-Fired Storage Water Heaters: Standard-Level Manufacturer Cost Increases

Energy Efficiency Level	Manufacturer Cost Increase *(2009$)*	
	32 gal	**50 gal**
1	$7.00	$9.00
2	$14.00	$16.00
3	$26.00	$26.00
4	$21.00	$24.00
5	$34.00	$35.00
6	$118.00	$117.00
7	$123.00	$123.00

Table 8.2.7 Gas-Fired Instantaneous Water Heaters: Standard-Level Manufacturer Cost Increases

Energy Efficiency Level	Manufacturer Cost Increase *(2009$)*
1	$15.00
2	$44.00
3	$154.00
4	$193.00
5	$488.00
6	$540.00
7	$620.00
8	$724.00

8.2.2.3 Overall Markup

The overall markup is the value determined by multiplying the manufacturer and other markups and the sales tax together to arrive at a single markup value. Table 8.2.8 shows the overall baseline and incremental markups for gas-fired water heaters. Refer to chapter 6, Markups to Determine Product Price, for details.

Table 8.2.8 Water Heaters: Overall Markups

Product Class	Baseline Cost Markup		Incremental Cost Markup	
	New Construction	Replacement	New Construction	Replacement
Gas-Fired Storage	2.43	2.06	1.92	1.66
Electric Storage	2.38	2.01	1.88	1.62
Oil-Fired Storage	2.41	2.04	1.91	1.64
Gas-Fired Instantaneous	2.55	2.20	2.11	1.88

8.2.2.4 Installation Cost

The installation cost is the cost to the consumer of installing the water heater. The cost of installation covers all labor and material costs associated with the replacement of an existing water heater or the installation of a water heater in a new home, as well as delivery, removal, and permit fees. Some design options may require unique installation costs. DOE's analysis recognizes these potential situations and incorporates the additional costs in the total installation price for those designs. DOE's analysis of installation costs makes use of the determination of water heater location for each sample household, as described in chapter 7.

DOE used regional labor costs to more accurately estimate installation costs by region. DOE then applied the appropriate regional labor cost to each RECS sample household.

Gas-Fired Storage Water Heaters. DOE developed installation costs for gas-fired storage water heaters using data from RS Means,[4] DOE technical support documents, [2, 3] and a consultant report prepared for this analysis.[2] See appendix 8-A, Installation Cost Determination, for details of the costs.

For water heaters in new homes, the basic installation cost includes adding a gas line branch and water piping, in addition to putting the new water heater in place and additional set-up. For natural draft venting in new construction, DOE accounted for both commonly-vented water heaters (together with a central furnace) and isolated water heaters (separately vented). For replacement cases, the installation cost includes disconnecting and removing the old water heater, removal/disposal fees, permit fees, as well as the cost of putting the new water heater in place and additional set-up.

For installations that include either a 65-gallon or 75-gallon water heater tank, and for installations in an attic, DOE added the cost of one additional labor hour for replacement installations and half of this for new construction.

Some houses may require a replacement drain pan of a larger size when a wider (due to increased insulation thickness) water heater is installed. DOE applied an additional drain pan cost as a function of the water heater rated volume for all water heaters with 2-inch insulation, which results in an incremental cost of $3.

In some houses, the original water heater location may be too small to accommodate a replacement water heater of the same rated volume when the new water heater's insulation thickness is 1.5 or 2 inches. Based on the consultant report, an estimated 15–25 percent of all replacement installations would require significant modifications in order to install a larger sized gas-fired storage water heater with 2-inch insulation. DOE estimated that such constraints would apply to half of the above fraction for replacement water heater installations with 1.5-inch insulation.

In situations where significant modifications would be required, there are a number of possibilities that might be applicable to the individual installation. These include:

1) Installing a water heater with different dimensions (e.g., installing a taller unit).
2) Installing a water heater with a smaller rated volume, increasing the setpoint, and adding a tempering valve to provide hot water at the desired temperature.
3) Installing a water heater with a smaller rated volume with a similar first hour rating as the existing unit (by either having a higher input capacity or more efficient burner)
4) Modifying the existing water heater installation location (primarily removing/replacing door jambs).
5) Relocating the water heater.
6) Switching to an electric or gas-fired instantaneous water heater or electric storage water heater.

After considering that some houses could choose a different dimension water heater (option 1), DOE assumed that, for non-manufactured homes, major modifications would be necessary for 20 percent of replacement installations with 2-inch insulation and for 10 percent of replacement installations with 1.5-inch insulation. Because manufactured homes encounter space constraints more often, DOE assumed that major modifications would be necessary for 40 percent of replacement installations with 2-inch insulation and for 20 percent of replacement installations with 1.5-inch insulation.

For those households facing major modifications, DOE estimated that half of the cases would choose option 2 (smaller water heater with tempering valve) or option 3 (smaller water heater with similar first hour rating as the existing unit) and half would select option 4 (door jamb removal/replacement). For single-family and multi-family homes, DOE estimated that option 4 would be selected only in cases where the water heater is installed in an indoor closet or attic (e.g., not in a garage or basement).

For option 2, DOE did not adjust the setpoint in its energy use calculations or change the equipment cost for the smaller water heater, as DOE believes these two factors would offset.[a] For option 3, DOE used the cost of installing tempering valves as a proxy for the increase in

[a] The tempering valve strategy involves increasing the setpoint temperature so that the total energy content of the water that can be delivered from the smaller water heater is equivalent to the content delivered by the original water heater at a lower temperature. Increasing the setpoint temperature will increase the water heater standby losses, which is generally offset by lower equipment cost for the smaller water heater.

equipment cost that would be associated with this option (DOE believes that the cost of adding the tempering valve would be in most cases greater than the cost of implementing option 3). For option 4, DOE estimated that door jamb removal/replacement would require 3.7 labor hours.

The efficiency levels that include electronic ignition, power vent, and condensing design have an increased installation cost relative to the baseline. For installation of water heaters with electronic ignition in new homes, DOE used the cost of the electrical outlet installation from the installation model developed for residential furnaces.[3] This approach assumes that power is readily available and that hookup into the existing wiring box is already covered by the regular installation cost. For replacement installations, DOE added an additional cost for installing an electrical outlet for houses that do not have electricity close to the water heater. DOE estimated that all households that do not have a gas furnace or boiler would require an electrical outlet and calculated the additional cost of the outlet using RS Means. DOE estimated that grounding for an electrical outlet is needed for houses built before 1960.

The incremental installation cost for the power vent design includes the cost of an electricity outlet and venting. The venting systems are configured to exit a side wall of a dwelling and are composed of plastic vent pipes. For replacement installations, DOE accounted for the installation of a new vent system and, for the commonly vented water heaters, for disconnecting the old unit from the existing common system.

The installation cost for the condensing design is the same as for the power vent design with the additional cost of the condensate disposal. This approach reflects the currently available condensing water heater design that utilizes a single pipe power vent design. The condensate disposal includes the cost of the condensate neutralizer filter, which is required by some codes. The condensate disposal includes the cost of the condensate neutralizer filter, which is required by some codes. DOE applied a condensate filter cost of $86 to 25 percent of the installations.

In comments on the NOPR, AGA expressed concerns about the safety of atmospheric venting at Efficiency Level 2. AGA referred to analysis by the Gas Technology Institute of vent temperatures from water heaters with high recovery efficiency, and voiced concern for recovery efficiencies of 78 percent and higher regarding condensation and the resulting corrosive environment in vent connectors during water heater cycling. AGA insisted that, for venting integrity and occupant safety, 100 percent of installations of units with recovery efficiency of 78 percent and higher should include the cost of a stainless steel vent connector.

DOE considered the information provided by AGA regarding the safety of atmospheric venting at Efficiency Level 2. Although there are several 40 gallon gas-fired water heater models currently available to consumers at 0.63 EF that utilize atmospheric venting and do not have any instructions directing installers to use special venting for these products, DOE believes that the prudent course is to assume that a stainless steel vent connector would be required for all models with RE of 78 percent and higher. Applying this assumption resulted in DOE using a cost for a stainless steel vent connector for 57 percent of installations at efficiency level 2, for 53 percent of installations at Efficiency Level 1, and for 24 percent of installations at baseline level.

The average and average incremental installation costs for gas-fired storage water heaters at each considered energy efficiency level are shown in Table 8.2.9.

Table 8.2.9 Average and Incremental Installation Cost for Gas-Fired Storage Water Heaters

Energy Efficiency Level	EF	Description	Installation Options	Average Installation Cost *(2009$)**	Incremental Installation Cost *(2009$)*
0	0.59	Standing Pilot, 1” ins	baseline, drain pan	630	
1	0.62	Standing Pilot, 1.5” ins	baseline, drain pan	703	74
2	0.63	Standing Pilot, 2” Ins	baseline, large drain pan, tempering valves, space constraints	736	106
3	0.64	Electronic ignition, 1” ins, power vent	baseline, drain pan, electricity, plastic vent	854	225
4	0.65	Electronic ignition, 1.5” ins, power vent	baseline, drain pan, electricity, plastic vent, tempering valves, space constraints	868	238
5	0.67	Electronic ignition, 2” ins, power vent	baseline, large drain pan, electricity, plastic vent, tempering valves, space constraints	885	255
6	0.77	Condensing, 2” ins, power vent	baseline, large drain pan, electricity, plastic vent, condensate filter, tempering valves, space constraints	905	275

*Average installation cost represents the weighted average cost for replacement and new construction applications.

Electric Storage Water Heaters. DOE developed installation costs for electric storage water heaters using data from RS Means[4] and other sources.[2, 5, 6] See appendix 8-A, Installation Cost Determination, for details of the costs.

For new construction water heaters, the basic installation cost includes adding water piping in addition to putting in place and setting up the new water heater. The basic installation cost for replacement cases includes the costs for putting in place and setting up the new water heater disconnecting, removing the old water heater, and removal/disposal fees and permit fees. DOE added an additional cost for installation of 66-, 80-, and 119-gallon electric water heaters, which takes into account one additional hour of labor for the extra time to install this larger equipment. Similarly, for installations in an attic, DOE added one additional labor hour.

Some houses may require a larger drain pan when a wider (due to increased insulation thickness) water heater is installed. For electric storage water heaters, DOE used the same approach as for gas-fired storage water heaters, and applied an incremental drain pan cost for all water heaters with 2-inch and greater insulation.

A certain fraction of households could incur additional installation costs when installing a water heater with a larger size due to increased insulation. Based on the consultant report, DOE estimated that 30–50 percent of all replacement installations would require significant modifications in order to install an electric storage water heater with 3 inch insulation. DOE estimated that such constraints would apply to half of the above fraction (i.e., 15–25 percent) for electric storage water heater installations with 2 inch insulation.

In situations where significant modifications would be required, there are a number of possibilities that might be applicable to the individual installation. These include:

1. Installing a water heater with different dimensions (e.g., installing a taller unit)
2. Installing a water heater with a smaller rated volume and adding a tempering valve to compensate for lower hot water delivery
3. Modifying the existing water heater installation location (including removing/replacing door jambs)
4. Relocating water heater
5. Switching to an electric or gas instantaneous water heater or gas storage water heater

After considering that some houses could choose a different dimension water heater (option 1), DOE assumed that major modifications would be necessary for 40 percent of replacement installations with 3 inch or greater insulation and for 20 percent of replacement installations with 2 inch or greater insulation. For these cases, the most common solutions would be installing a water heater with a smaller rated volume and adding a tempering valve (option 2) or removing/replacing door jambs (option 3). The other installation possibilities have a much lower probability of occurring. DOE estimated that half of the cases where major modifications would be necessary would choose option 2 (tempering valves)[b] and half would select option 3 (door jamb removal/replacement). DOE estimated that option 3 would be selected only in cases where the water heater is installed in an indoor closet or attic (e.g., not in a garage or basement).

For option 2, DOE did not adjust the setpoint in its energy use calculations or change the equipment cost for the smaller water heater, as DOE believes these two factors would offset.[c] For option 3, DOE estimated that door jamb removal/replacement would require 3.7 labor hours.

For heat pump water heater installation, DOE applied several additional costs, including one additional hour of labor for the extra time required to install this product. Since many electric storage water heaters are installed near a drain, DOE estimates that only one quarter of all heat pump water heater installations would require addition of a condensate pump and longer

[b] Tempering valve was applied to water heaters with 2.5 in. or greater insulation.

[c] The tempering valve strategy involves increasing the setpoint temperature so that the total energy content of the water that can be delivered from the smaller water heater is equivalent to the content delivered by the original water heater at a lower temperature. Increasing the setpoint temperature will increase the water heater standby losses, which is generally offset by lower equipment cost for the smaller water heater.

water line to the drain (at an average cost of $154). DOE also applied an additional drain pan cost to account for the larger insulation for this product.

DOE assumed that the space constraints encountered when installing heat pump water heaters would be similar to those encountered when installing electric storage water heaters with 3 inch insulation. In addition, heat pump water heaters are required to be in well-ventilated spaces. Based on the water heater location, for the NOPR DOE estimated that (1) 40 percent of replacement installations would encounter space constraints, (2) half of the cases (where ventilation is not a significant issue) would choose a smaller water heater with a higher setpoint and a tempering valve, and (3) the other half (where ventilation is an issue) would choose door jambs removal/replacement and adding a louvered door.

Regarding the use of a smaller water heater with a higher setpoint and a tempering valve, for the final rule DOE reduced the fraction of installations that would use a tempering valve to include only those cases where the water heater setpoint would not need to exceed 140°F, as recommended in GE product literature. DOE assumed that those households for which the tempering valve strategy is not viable would incur costs to modify the space to accommodate the heat pump water heater.

Regarding the approach of adding a louvered door, DOE believes that there are legitimate concerns about the extent to which installing a louvered door will provide adequate air flow for closet installations of heat pump water heaters. For the final rule analysis, DOE decreased the number of cases using door jambs removal/replacement and adding a louvered door from 20 percent to 15 percent (at an estimated average cost of $325). DOE assumed that some households would instead install a venting system, which would provide adequate air flow and also alleviate excessive cooling of the indoor space near the water heater (see discussion below).

Heat pump water heaters installed in a conditioned space can increase heating loads during the heating season. DOE estimated that about 35 percent of households in the subsample for electric water heaters would experience significant indoor cooling due to operation of the heat pump water heater in the heating months ("significant" means that the heat pump water heater adds 3 MMBtu to the indoor space over the heating season). Using calculations specific to each household in the subsample for electric water heaters, DOE estimated that all indoor replacement installations where the household would face a significant cooling effect would incur the cost of having a venting system installed to exhaust and supply air, which averages $469.[d] (For new construction, the unit is assumed to be installed in a space where this is not an issue.) DOE estimated that that in some cases it would be necessary to install the venting system outside the wall structure, where the exposed vents would likely be covered. Therefore, it assumed that one-fourth of the venting system installations would incur an additional cost (on average $581) for covering the exposed vents.

[d] For the remainder of homes experiencing a cooling effect, the extra cost for space heating is accounted for in the energy use calculations, as described in chapter 7.

The average and average incremental installation costs for electric storage water heaters at each considered energy efficiency level are shown in Table 8.2.10.

Table 8.2.10 Average and Incremental Installation Cost for Electric Storage Water Heaters

Energy Efficiency Level	EF	Description	Installation Options	Average Installation Cost *(2009$)**	Incremental Installation Cost *(2009$)*
0	0.90	1.5 in (Baseline)	Baseline	288	
1	0.91	2 in	baseline, large drain pan, tempering valves, space constraints	311	23
2	0.92	2.25 in	baseline, large drain pan, tempering valves, space constraints	322	34
3	0.93	2.5 in	baseline, large drain pan, tempering valves, tempering valves, space constraints	330	42
4	0.94	3 in	baseline, large drain pan, tempering valves, space constraints	349	61
5	0.95	3 to 4 in	baseline, large drain pan, tempering valves, space constraints	349	61
6	2.00	Heat Pump Water Heater Integrated Design	baseline, large drain pan, space constraints	535	248
7	2.35	Heat Pump Water Heater Integrated Design	baseline, large drain pan, space constraints	539	252

*Average installation cost represents the weighted average cost for replacement and new construction applications.

***Oil-Fired Storage Water Heaters*.** DOE developed installation cost data for the baseline oil-fired storage water heater using information from the 2001 water heater rulemaking.[4] An oil-fired storage water heater installation requires hot and cold water connections, oil supply, electrical power connection, a vent connection and an oil-burner that consists of oil pump, blower, ignition device, and controls.

Residential oil-fired storage water heaters are typically sold and installed by local residential heating oil dealers. For the 2001 rulemaking, DOE gathered installation cost information from seven dealers in the northeastern United States. These data show a very wide range of installation costs, which vary significantly in different areas depending on the size of the markets. The typical installation cost for a new oil-fired storage water heater ranges from $462 to $981 (2007$), with an average cost of $625.

DOE assumed that a new burner is already installed and therefore there is no additional installation cost for 2 and 2.5 inch oil-fired storage water heaters. DOE also assumed that there is no additional venting cost associated with efficiency levels 6 and 7.

Table 8.2.11 presents the average and average incremental installation cost for oil-fired storage water heaters at the considered energy efficiency levels.

Table 8.2.11 Average and Incremental Installation Cost for Oil-Fired Storage Water Heaters

Energy Efficiency Level	EF	Description	Installation Options	Average Installation Cost *(2009$)**	Incremental Installation Cost *(2009$)*
0	0.53	Electronic Ignition, 1" ins (fiberglass)	Baseline	646	
1	0.54	Electronic Ignition, 1.5" ins (fiberglass)	Baseline	646	0
2	0.56	Electronic Ignition, 2" ins (fiberglass)	Baseline	646	0
3	0.58	Electronic Ignition, 2.5" ins (fiberglass)	Baseline	646	0
4	0.60	Electronic Ignition, 2" ins (foam)	Baseline	646	0
5	0.62	Electronic Ignition, 2.5" ins (foam)	Baseline	646	0
6	0.66	Electronic Ignition, 1" ins (fiberglass), enhanced flue baffle	Baseline	646	0
7	0.68	Electronic Ignition, 1" ins (foam), enhanced flue baffle	Baseline	646	0

*Average installation cost represents the weighted average cost for replacement and new construction applications.

Gas-Fired Instantaneous Water Heaters. DOE developed installation cost data for gas-fired instantaneous water heaters using RS Means,[3, 4, 5, 6, 7] DOE technical support documents,[3, 4, 5, 6, 7] and a consultant report prepared for this analysis.[2] All replacements are assumed to be conversions from gas-fired storage water heaters; this reflects the small number of instantaneous water heaters installed during the 1980s and 1990s and the long lifetime of these products. It can be difficult to use instantaneous water heaters as a replacement technology in some existing homes, since physically accommodating their installation can add considerable expense.[5] DOE's derivation of installation cost does not consider extreme installation configurations, as DOE believes that households with physical limitations will not choose to convert from a gas-fired storage water heater.

For new construction applications, the installation cost includes adding a gas line branch (since in most cases it is not possible to connect the water heater to the existing house gas line, which is too small), installing a vent system, adding water piping, and putting in place and setting up the new water heater. For replacement cases, the installation cost includes the labor for disconnecting and removing the old water heater, removal/disposal fee, permit fee, and putting in place and setting up the new instantaneous water heater, including the venting system. The analysis for both new construction and replacements assumes Category I vertical venting using non-stainless steel vents. See appendix 8-A, Installation Cost Determination, for details.

For installations of gas-fired instantaneous water heaters with electronic ignition, DOE included an additional cost to account for labor and wiring for installing an electrical outlet for houses that do not have electricity close to the water heater. DOE used the same approach it applied to gas-fired storage water heaters.

The incremental installation cost for the power vent design includes the cost of the electricity outlet and the required venting. The cost reflects Category III horizontal venting using stainless steel vents. For replacement installations, DOE estimated that half of the installations will use vertical vents and half will use horizontal vents. For replacement installations, DOE accounted for the installation of a new vent system, and for commonly-vented water heaters, for disconnecting from the existing common system.

The installation cost for the condensing design also includes plastic vents and the cost of the condensate disposal.

The average and average incremental installation costs for gas-fired instantaneous water heaters at the considered efficiency levels are shown in Table 8.2.12.

Table 8.2.12 Average and Incremental Installation Cost for Gas-Fired Instantaneous Water Heaters

Energy Efficiency Level	**EF**	**Description**	**Installation Options**	**Average Installation Cost** *(2009$)******	**Incremental Installation Cost** *(2009$)*
0	0.62	Standing pilot (Baseline)	Natural Draft Venting	1045	
1	0.69	Standing Pilot, Improved HX	Natural Draft Venting	1045	0
2	0.78	Electronic Ignition, Improved HX	Forced Draft Venting, Electricity	1272	227
3	0.80	Electronic Ignition, Induced Draft (Power Vent)	Forced Draft Venting, Electricity	1272	227
4	0.82	Electronic Ignition, Improved HX, Induced Draft (Power Vent)	Forced Draft Venting, Electricity	1272	227
5	0.84	Electronic Ignition, Improved HX, Induced Draft (Power Vent)	Forced Draft Venting, Electricity	1272	227
6	0.85	Electronic Ignition, Improved HX, Induced Draft (Power Vent)	Forced Draft Venting, Electricity	1272	227
7	0.92	Condensing	Condensing (plastic venting), Electricity	960	-85
8	0.95	Condensing	Condensing (plastic venting), Electricity	960	-85

*Average installation cost represents the weighted average cost for replacement and new construction installations.

8.2.2.5 Total Installed Price

The total installed price is the sum of the consumer product price and the installation cost. Refer back to section 8.2 to see the equations that DOE used to calculate the total installed price for baseline and standard-level products. Table 8.2.13 through Table 8.2.16 present the average consumer product price, installation costs, and total installed price for each product class at the baseline level and each considered energy efficiency level.

Table 8.2.13 Gas-Fired Storage Water Heaters: Average Consumer Product Price, Installation Cost, and Total Installed Price

Energy Efficiency Level	Energy Factor	Product Price *(2009$)*	Installation Cost *(2009$)*	Total Installed Price *(2009$)*
Baseline	0.59	$450	$630	$1,079
1	0.62	$468	$703	$1,171
2	0.63	$509	$736	$1,244
3	0.64	$705	$854	$1,559
4	0.65	$723	$868	$1,591
5	0.67	$771	$885	$1,656
6	0.77	$988	$905	$1,893

Table 8.2.14 Electric Storage Water Heaters: Average Consumer Product Price, Installation Cost, and Total Installed Price

Energy Efficiency Level	Energy Factor	Product Price *(2009$)*	Installation Cost *(2009$)*	Total Installed Price *(2009$)*
Baseline	0.90	$281	$288	$569
1	0.91	$291	$311	$602
2	0.92	$301	$322	$623
3	0.93	$304	$330	$634
4	0.94	$325	$349	$674
5	0.95	$362	$349	$711
6	2.00	$1,039	$535	$1,575
7	2.35	$1,163	$539	$1,703

Table 8.2.15 Oil-Fired Storage Water Heaters: Average Consumer Product Price, Installation Cost, and Total Installed Price

Energy Efficiency Level	Energy Factor	Product Price *(2009$)*	Installation Cost *(2009$)*	Total Installed Price *(2009$)*
Baseline	0.53	$1,328	$646	$1,974
1	0.54	$1,342	$646	$1,988
2	0.56	$1,355	$646	$2,001
3	0.58	$1,380	$646	$2,026
4	0.60	$1,367	$646	$2,013
5	0.62	$1,394	$646	$2,040
6	0.66	$1,534	$646	$2,180
7	0.68	$1,534	$646	$2,180

Table 8.2.16 Gas-Fired Instantaneous Water Heaters: Average Consumer Product Price, Installation Cost, and Total Installed Price

Energy Efficiency Level	Energy Factor	Product Price *(2009$)*	Installation Cost *(2009$)*	Total Installed Price *(2009$)*
Baseline	0.62	$734	$1,045	$1,779
1	0.69	$764	$1,045	$1,808
2	0.78	$820	$1,272	$2,091
3	0.80	$1,033	$1,272	$2,305
4	0.82	$1,109	$1,272	$2,380
5	0.84	$1,680	$1,272	$2,952
6	0.85	$1,781	$1,272	$3,053
7	0.92	$1,936	$960	$2,896
8	0.95	$2,138	$960	$3,097

8.2.3 Direct Heating Equipment

8.2.3.1 Baseline Manufacturer Cost

Table 8.2.17 shows the baseline manufacturer cost for each of the direct heating equipment product classes, estimated as described in chapter 5, Engineering Analysis.

Table 8.2.17 Direct Heating Equipment: Baseline Manufacturer Costs

Product Class	**Baseline AFUE**	**Manufacturer Cost** *(2009$)*
Gas Wall Fan DHE	74%	$363.64
Gas Wall Gravity DHE	64%	$214.45
Gas Floor DHE	57%	$369.85
Gas Room DHE	64%	$234.14
Gas Hearth DHE	64%	$371.92

8.2.3.2 Standard-Level Manufacturer Cost Increases

DOE developed manufacturer cost increases associated with increases in energy efficiency levels of direct heating equipment as described in chapter 5, Engineering Analysis. Table 8.2.18 through Table 8.2.22 summarize the standard-level manufacturer cost increases for each direct heating equipment product class.

Table 8.2.18 Gas Wall Fan DHE: Standard-Level Manufacturer Cost Increases

Energy Efficiency Level	**AFUE**	**Manufacturer Cost Increase** *(2009$)*
1	75%	$25.90
2	76%	$37.30
3	77%	$58.02
4	80%	$118.10

Table 8.2.19 Gas Wall Gravity DHE: Standard-Level Manufacturer Cost Increases

Energy Efficiency Level	**AFUE**	**Manufacturer Cost Increase** *(2009$)*
1	66%	$27.97
2	68%	$44.55
3	69%	$80.81
4	70%	$142.45

Table 8.2.20 Gas Floor DHE: Standard-Level Manufacturer Cost Increases

Energy Efficiency Level	**AFUE**	**Manufacturer Cost Increase** *(2009$)*
1	58%	$24.86

Table 8.2.21 Gas Room DHE: Standard-Level Manufacturer Cost Increases

Energy Efficiency Level	AFUE	Manufacturer Cost Increase *(2009$)*
1	65%	$15.54
2	66%	$31.08
3	67%	$38.33
4	68%	$47.66
5	83%	$186.48

Table 8.2.22 Gas Hearth DHE: Standard-Level Manufacturer Cost Increases

Energy Efficiency Level	AFUE	Manufacturer Cost Increase *(2009$)*
1	67%	-$2.07
2	72%	$178.19
3	93%	$545.97

8.2.3.3 Overall Markup

The overall markup is the value determined by multiplying the manufacturer and other markups and the sales tax together to arrive at a single markup value. In turn, DOE multiplied the overall markup by the baseline or standard-level manufacturer cost to arrive at the price paid by the consumer for the product. DOE estimated a baseline markup (i.e., a markup used to convert the baseline manufacturer cost into a consumer price) and an incremental markup (i.e., a markup used to convert an incremental manufacturer cost due to a standard level into an incremental consumer price). Table 8.2.23 shows the overall markups for direct heating equipment. Refer to chapter 6, Markups to Determine Product Price, for details.

Table 8.2.23 Direct Heating Equipment: Overall Markups

Product Class	Replacement Applications		New Home Applications	
	Baseline	Incremental	Baseline	Incremental
Gas Wall Fan	2.52	2.00	3.15	2.49
Gas Wall Gravity	2.52	2.00	3.15	2.49
Gas Floor	2.52	2.00	3.15	2.49
Gas Room	2.51	2.99	3.15	2.49
Gas Hearth	2.51	2.98	3.15	2.49

8.2.3.4 Installation Cost

DOE derived baseline installation costs for direct heating equipment using the approach from the 1993 TSD.[6] For gas wall gravity DHE, gas room DHE, and gas hearth DHE, DOE included an additional installation cost for the design options that require electricity. DOE included this cost for the replacement market only, since in new construction the wiring is considered part of the general electrical work. DOE determined the cost of an additional electrical outlet to be $183 for gas wall gravity DHE, $159 for gas room DHE, and $169 for gas hearth DHE. DOE estimated that grounding for an electrical outlet is needed for houses build before 1960 at a cost of $37 for gas wall gravity DHE, $32 for gas room DHE, and $34 for gas hearth DHE.[7]

In addition, DOE included an additional installation cost of $80 for the design options requiring stainless steel venting (e.g. 83 percent gas room DHE efficiency level). For gas hearth DHE condensing efficiency levels, DOE did not include any cost adder. DOE considered that on average the additional installation cost in replacement applications is offset by the decreased installation costs for new owners and new construction.

DOE assumes that for the max tech level for gas fan wall furnace DHE (80% AFUE), adding to the heat exchanger to increase efficiency will make upright models bigger such that they may not be able to fit in the same space as the unit they are replacing. As a result, DOE added installation cost associated with the carpentry cost for cutting and repairing the wall to increase the dimensions of the wall opening for a fraction of installations, as well as making some venting modifications The fraction takes into account that some installations are "console units" and do not have this issue, and that some upright installations are not installed inside the wall and therefore do not have this issue. The average cost is $142 for the carpentry work and $50 for venting modifications.

Table 8.2.24 through Table 8.2.28 summarize the average installation costs for each product class. Average installation cost represents the weighted average cost for replacement and new construction applications.

Table 8.2.24 Average Installation Cost for Gas Wall Fan DHE

Energy Efficiency Level	AFUE	Description	Installation Options	Average Installation Cost *(2009$)*	Incremental Installation Cost *(2009$)*
0	74%	Standing Pilot	Baseline	861	
1	75%	Electronic ignition, two-speed blower	Baseline	861	0
2	76%	Electronic ignition, improved HX	Baseline	861	0
3	77%	Electronic ignition, two-speed blower, improved HX	Baseline	861	0
4	80%	Electronic ignition, induced draft	Baseline	973	113

Table 8.2.25 Average Installation Cost for Gas Wall Gravity DHE

Energy Efficiency Level	AFUE	Description	Installation Options	Average Installation Cost *(2009$)*	Incremental Installation Cost *(2009$)*
0	64%	Standing pilot	Baseline	861	
1	66%	Standing pilot, improved HX	Baseline	861	0
2	68%	Standing pilot, improved HX	Baseline	861	0
3	69%	Standing pilot, improved HX	Baseline	861	0
4	70%	Electronic ignition	Baseline, Electricity	1042	182

Table 8.2.26 Average Installation Cost for Gas Floor DHE

Energy Efficiency Level	AFUE	Description	Installation Options	Average Installation Cost *(2009$)*	Incremental Installation Cost *(2009$)*
0	57%	Standing pilot	Baseline	1223	
1	58%	Standing pilot, improved HX	Baseline	1223	0.0

Table 8.2.27 Average Installation Cost for Gas Room DHE

Energy Efficiency Level	AFUE	Description	Installation Options	Average Installation Cost *(2009$)*	Incremental Installation Cost *(2009$)*
0	64%	Standing Pilot	Baseline	585	
1	65%	Standing pilot, improved HX	Baseline	585	0.0
2	66%	Standing pilot, improved HX	Baseline	585	0.0
3	67%	Standing pilot, improved HX	Baseline	585	0.0
4	68%	Standing pilot, improved HX	Baseline	585	0.0
5	83%	Electronic Ignition, Dual Shaft Blower, Electronic Controls	Baseline, Electricity, Stainless Steel Vent	823	238

Table 8.2.28 Average Installation Cost for Gas Hearth DHE

Energy Efficiency Level	AFUE	Description	Installation Options	Average Installation Cost *(2009$)*	Incremental Installation Cost *(2009$)*
0	64%	Standing Pilot	Baseline	617	
1	67%	Electronic Ignition	Baseline, Electricity	703	87
2	72%	Electronic Ignition, Fan Assisted (Blower)	Baseline, Electricity	703	87
3	93%	Condensing	Baseline, Electricity, Condensing	703	87

8.2.3.5 Total Installed Price

The total installed price is the sum of the consumer product price and the installation cost. Refer back to section 8.2 to see the equations DOE used to calculate the total installed price for baseline and standard-level products. Table 8.2.29 through Table 8.2.33 present the consumer product prices, installation costs, and total installed price for the five direct heating equipment product classes.

Table 8.2.29 Gas Wall Fan DHE: Average Consumer Product Price, Installation Cost, and Total Installed Price

Energy Efficiency Level	AFUE	Product Price *(2009$)*	Installation Cost *(2009$)*	Total Installed Price *(2009$)*
Baseline	74%	$971	$861	$1,832
1	75%	$1,027	$861	$1,888
2	76%	$1,052	$861	$1,912
3	77%	$1,097	$861	$1,957
4	80%	$1,227	$973	$2,200

Table 8.2.30 Gas Wall Gravity DHE: Average Consumer Product Price, Installation Cost, and Total Installed Price

Energy Efficiency Level	AFUE	Product Price *(2009$)*	Installation Cost *(2009$)*	Total Installed Price *(2009$)*
Baseline	64%	$573	$861	$1,433
1	66%	$633	$861	$1,494
2	68%	$669	$861	$1,530
3	69%	$748	$861	$1,609
4	70%	$882	$1,042	$1,924

Table 8.2.31 Gas Floor DHE: Average Consumer Product Price, Installation Cost, and Total Installed Price

Energy Efficiency Level	AFUE	Product Price *(2009$)*	Installation Cost *(2009$)*	Total Installed Price *(2009$)*
Baseline	57%	$987	$1,223	$2,209
1	58%	$1,041	$1,223	$2,263

Table 8.2.32 Gas Room DHE: Average Consumer Product Price, Installation Cost, and Total Installed Price

Energy Efficiency Level	AFUE	Product Price *(2009$)*	Installation Cost *(2009$)*	Total Installed Price *(2009$)*
Baseline	64%	$623	$585	$1,208
1	65%	$656	$585	$1,242

2	66%	$690	$585	$1,275
3	67%	$706	$585	$1,291
4	68%	$726	$585	$1,311
5	83%	$1,026	$823	$1,849

Table 8.2.33 Gas Hearth DHE: Average Consumer Product Price, Installation Cost, and Total Installed Price

Energy Efficiency Level	AFUE	Product Price *(2009$)*	Installation Cost *(2009$)*	Total Installed Price *(2009$)*
Baseline	64%	$986	$617	$1,603
1	67%	$982	$703	$1,685
2	72%	$1,370	$703	$2,074
3	93%	$2,163	$703	$2,867

8.2.4 Gas-Fired Pool Heaters

8.2.4.1 Baseline Manufacturer Cost

DOE developed the baseline manufacturer costs for gas-fired pool heaters shown in Table 8.2.34 as described in chapter 5, Engineering Analysis.

Table 8.2.34 Gas-Fired Pool Heaters: Baseline Manufacturer Cost

Energy Efficiency Level	Manufacturer Cost *(2009$)*
78% - Standing Pilot	$568.00
78% - Electronic Ignition	$587.00

8.2.4.2 Standard-Level Manufacturer Cost Increases

DOE developed manufacturing cost increases associated with increases in product energy efficiency levels for gas-fired pool heaters (Table 8.2.35) as described in chapter 5, Engineering Analysis.

Table 8.2.35 Gas-Fired Pool Heaters: Standard-Level Manufacturer Cost Increases

Energy Efficiency Level	Thermal Efficiency	Manufacturer Cost Increase *(2009$)*	
		Standing Pilot	Electronic Ignition
1	79%	$11.00	$11.00
2	81%	$25.00	$25.00
3	82%	$58.00	$58.00
4	83%		$129.00
5	84%		$191.00
6	86%		$444.00
7	90%		$941.00
8	95%		$1,082.00

8.2.4.3 Overall Markup

The overall markup is the value determined by multiplying the manufacturer and other markups and the sales tax together to arrive at a single markup value. Table 8.2.36 shows the overall baseline and incremental markups for gas-fired pool heaters. Refer to chapter 6, Markups to Determine Product Price, for details.

Table 8.2.36 Gas-Fired Pool Heaters: Overall Markups

	Replacement Applications		New Home Applications	
	Baseline	Incremental	Baseline	Incremental
Overall	2.08	1.75	2.30	1.82

8.2.4.4 Installation Cost

DOE derived installation cost data for the baseline pool heater using RS Means[8] and information in a consultant report.[9] The baseline unit represents a pool heater with a pilot light. For new construction applications, the installation cost includes adding a gas line from the gas meter to the pool heater (in most cases it is not possible to connect the pool heater to the existing house gas line as it is too small). It also includes adding PVC lines from the pool pump to the inlet and outlet water headers of the pool heater (thermal isolation - non - PVC pipe is usually part of this line to prevent pool pump overheating). The installation cost also includes setting, connection and start-up fees. For the replacement applications, the installation cost includes disconnecting and removing the old pool heater, putting in place the new unit and reconnecting the gas and PVC lines.

For units with electronic ignition, DOE included an additional installation cost to account for adding an electrical line (115V) and a separate junction box. These are needed since the pool heater requires lower amperage than the pool pump.

The incremental installation cost for the condensing design includes the cost of the condensate drain piping that goes from the pool heater to a P-trap device[e] located at the sewer line entrance.[9]

In the NOPR analysis, DOE included a cost for adding electricity at efficiencies above 82 percent (which use electronic ignition only) for installations where the unit currently uses a pilot light. DOE estimated that 26.5 percent of installations would incur this cost. Commenting on the NOPR, Raypak stated that 8 percent of pool heaters are millivolt pool heaters (i.e., use a pilot light), and the cost of adding electricity is not insignificant. (Raypak, No. 67 at p. 2) For the final rule, DOE has adopted the 8 percent value provided by Raypak to estimate the fraction of installations that would require addition of electricity at efficiencies above 82 percent.

Table 8.2.37 shows the average and incremental installation cost for pool heaters at each energy efficiency level. Average installation cost represents the weighted average cost for replacement and new constructions.

Table 8.2.37 Average and Incremental Installation Cost for Pool Heaters

Energy Efficiency Level	EF	Description	Installation Options	Average Installation Cost *(2009$)*	Incremental Installation Cost *(2009$)*
0	78%	Baseline -pilot or elect. Ignition	Baseline	1936	
1	79%	Improved HX	Baseline	1936	0
2	81%	Improved HX	Baseline	1936	0
3	82%	Improved HX	Baseline	1936	0
4	83%	Power Venting	Baseline, Electrical Outlet	1947	11
5	84%	Power Venting, improved HX	Baseline, Electrical Outlet	1947	11
6	86%	Sealed Combustion, improved HX	Baseline, Electrical Outlet, Condensing Adder	2048	112
7	90%	Sealed combustion, condensing	Baseline, Electrical Outlet, Condensing Adder	2048	112
8	95%	Sealed combustion, condensing, improved HX	Baseline, Electrical Outlet, Condensing Adder	2048	112

8.2.4.5 Total Installed Price

The total installed price is the sum of the consumer product price and the installation cost. Refer back to section 8.2 to see the equations that DOE used to calculate the total installed price for baseline and standard-level products. Table 8.2.38 presents the average consumer product

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[e] A "P-trap" is required by many city codes. It helps to isolate the condensate from back-flowing into the pool water and prevents the sewer gas from back-flowing.

price, installation costs, and total installed price for pool heaters at each considered energy efficiency level.

Table 8.2.38 Gas-Fired Pool Heaters: Average Consumer Product Price, Installation Cost, and Total Installed Price

Energy Efficiency Level	Thermal Efficiency	Product Price *(2009$)*	Installation Cost *(2009$)*	Total Installed Price *(2009$)*
Baseline	78%	$1,304	$1,936	$3,240
1	79%	$1,324	$1,936	$3,260
2	81%	$1,349	$1,936	$3,285
3	82%	$1,408	$1,936	$3,344
4	83%	$1,537	$1,947	$3,484
5	84%	$1,647	$1,947	$3,594
6	86%	$2,098	$2,048	$4,146
7	90%	$2,984	$2,048	$5,032
8	95%	$3,235	$2,048	$5,283

8.3 OPERATING COST INPUTS - OVERVIEW

DOE defines the operating cost by the following equation:

$$OC = EC + RC + MC$$

Where:

EC = Energy expenditure associated with operating the product,
RC = Repair cost associated with component failure, and
MC= Service cost for maintaining product operation.

Table 8.3.1 shows the inputs for determining the annual operating costs and their discounted value over the product lifetime.

Table 8.3.1 Inputs for Operating Cost

Annual Energy Consumption
Energy Prices and Price Trends
Repair and Maintenance Costs
Product Lifetime
Discount Rate
Effective Date of Standard

The *annual energy consumption* is the site energy use associated with operating the product. The annual energy consumption varies with the product energy efficiency. *Energy prices* are the prices paid by consumers for electricity, gas, or oil. Multiplying the annual energy consumption by the appropriate energy prices yields the annual energy cost. DOE used *energy price trends* to forecast energy prices into the future and, along with the product lifetime and discount rate, to establish the lifetime energy costs. *Repair costs* are associated with repairing or replacing components that have failed. *Maintenance costs* are associated with maintaining the operation of the product. The *product lifetime* is the age at which the product is retired from service. The *discount rate* is the rate at which DOE discounted future expenditures to establish their present value.

DOE calculated the operating cost for baseline products based on the following equation:

$$
\begin{aligned}
OC_{BASE} &= EC_{BASE} + RC_{BASE} + MC_{BASE} \\
&= AEC_{BASE} \times PRICE_{ENERGY} + RC_{BASE} + MC_{BASE}
\end{aligned}
$$

Where:

OC_{BASE} =	Baseline operating cost,
EC_{BASE} =	Energy expenditure associated with operating the baseline product,
RC_{BASE} =	Repair cost associated with component failure for the baseline product,
MC_{BASE} =	Cost for maintaining baseline product operation,
AEC_{BASE} =	Annual energy consumption for baseline product,
$PRICE_{ENERGY}$ =	Energy price.

DOE calculated the operating cost for standard-level products based on the following equation:

$$
\begin{aligned}
OC_{STD} &= EC_{STD} + RC_{STD} + MC_{STD} \\
&= AEC_{STD} \times PRICE_{ENERGY} + RC_{STD} + MC_{STD} \\
&= \left(AEC_{BASE} - \Delta AEC_{STD}\right) \times PRICE_{ENERGY} \\
&\quad + \left(RC_{BASE} + \Delta RC_{STD}\right) + \left(MC_{BASE} + \Delta MC_{STD}\right)
\end{aligned}
$$

Where:

OC_{STD} =	Standard-level operating cost,
EC_{STD} =	Energy expenditure associated with operating standard-level products,
RC_{STD} =	Repair cost associated with component failure for standard-level products,
MC_{STD} =	Service cost for maintaining standard-level product operation,
AEC_{STD} =	Annual energy consumption for standard-level products,
$PRICE_{ENERGY}$ =	Energy price,

ΔAEC_{STD} =	Change in annual energy consumption caused by standard-level products,
ΔRC_{STD} =	Change in repair cost caused by standard-level products, and
ΔMC_{STD} =	Change in maintenance cost caused by standard-level products.

As the above equations show, DOE multiplied the annual energy consumption by the energy price to derive the energy component of operating costs. For direct heating equipment and pool heaters, DOE used annual average energy prices. For water heaters, DOE estimated energy consumption on a monthly basis, and therefore also generated monthly average energy prices.

The following sections provide information about each of the above input variables that DOE used to calculate the operating costs for heating products.

8.4 ANNUAL ENERGY CONSUMPTION

As described in chapter 7, Energy Use Characterization, and the beginning of this chapter in section 8.1.1, DOE developed a sample of individual households that use each of the considered products. By developing household samples, DOE was able to account for the variability in both energy use and energy price associated with each household. Refer back to chapter 7 to review the parameters that define the variability of annual energy consumption for the heating products as well as the annual energy consumption results.

8.4.1 Accounting for the Rebound Effect

A rebound effect (also called a take-back effect or offsetting behavior) refers to increased energy consumption resulting from actions that increase energy efficiency and reduce consumer costs. The logic behind the rebound effect is that more energy efficient products lower the marginal cost of the end-use service relative to lower energy efficient products. Because the marginal cost of the service is reduced, a service demand response occurs. For example, a home insulation program that reduces heat losses by 50 percent does not usually result in a full 50 percent reduction in energy consumption, because residents of insulated homes find that they can afford to keep their homes warmer. As a result, they reinvest a portion of potential energy savings on comfort.

To determine the impact of the rebound effect on energy efficiency improvement for the heating products considered in this rulemaking, DOE searched the literature on the rebound effect, and also considered how the National Energy Modeling System (NEMS), which is used for developing EIA's *Annual Energy Outlook* (*AEO*), incorporates a rebound effect.

For water heaters, DOE found that NEMS does not incorporate a rebound factor. DOE reviewed a summary of studies regarding the rebound effect that concluded “technical improvements for residential hot water heating will be between 60 and 90 percent effective in reducing energy consumption for this service" (implying a rebound effect of 10 to 40 percent).[10] Another study examining the rebound effect cites a best-guess value for “other services” (which include water heating) of less than 20 percent, but with a low degree of confidence.[11] Balancing the available information, DOE chose to use a rebound effect of 10 percent for all water heaters.

For direct heating equipment, DOE considered a summary of studies regarding the rebound effect in relation to space heating products.[10] Based on five studies chosen for their robust methodology, the summary concluded that, for a 100 percent increase in fuel efficiency, values of "take-back" or rebound for space heating are between 10 and 30 percent of the energy consumption savings. It noted that NEMS incorporates a rebound effect for space heating that results in a 0.15 percent increase in energy consumption for a one-percent increase in energy efficiency. In keeping with the approach in NEMS, DOE chose to apply a rebound effect of 15 percent in its analysis of direct heating equipment.

For pool heaters, DOE found no mention of a rebound effect in the literature. However, since economic theory suggests that there should be some take-back associated with a reduction in the marginal cost of service, DOE included a rebound effect of 10 percent for pool heaters in its analysis.

The take-back in energy consumption associated with the rebound effect provides consumers with increased value (e.g., a warmer indoor environment). The net impact on consumers is thus the sum of the change in the cost of owning the heating products (i.e., life-cycle cost) and the increased value for the warmer indoor environment. DOE believes that the increased value to consumers added by the rebound effect is similar in value to the foregone energy savings. Therefore, DOE estimated that this value is equivalent to the monetary value of the energy savings that would have occurred without the rebound effect. Thus, the economic impacts on consumers with or without the rebound effect, as measured in the LCC analysis, are the same.

8.5 ENERGY PRICES AND ENERGY PRICE TRENDS

Using data from EIA, DOE calculated average annual energy prices for each of 13 geographic areas: the nine U.S. Census Divisions and four large States (California, Florida, New York, and Texas) treated separately. For Census Divisions containing one of these large States, DOE calculated the regional average values leaving out data for the large State—for example, the Pacific division average does not include California, and the West South Central division does not include Texas.

To be able to determine monthly prices for use in the water heater analysis, DOE developed monthly energy price factors for each fuel. For a detailed discussion of the development of monthly energy price factors, see appendix 8-E, Monthly Energy Price Factor Calculations.

As noted earlier, DOE used RECS to develop a sample of individual households that use each of the three products. By developing household samples, DOE was able to perform the LCC and PBP calculations for each household to account for the regional variability in energy prices.

8.5.1 Residential Natural Gas Prices

DOE collected 2008 natural gas prices from EIA's Natural Gas Navigator, which includes natural gas prices for residential, commercial, and industrial consumers by State.[12] The EIA's Natural Gas Navigator provides monthly natural gas prices. DOE weighted the residential natural gas prices for each State by the number of natural gas consumers in each State[12] and transformed the values from units of $/tcf to $/MMBtu. Finally, DOE aggregated the prices by 13 geographic areas: the nine US Census Divisions and four large states. Table 8.5.1 displays the 2008 average natural gas prices for each region.

Table 8.5.1 Average Residential Natural Gas Prices in 2008

Geographic Area	Average *(2009$/MMBtu)*
CD 1 - New England	17.92
CD 2 - Middle Atlantic (excludes NY)	16.67
CD 3 - East North Central	14.52
CD 4 - West North Central	14.58
CD 5 - South Atlantic (excludes FL)	19.65
CD 6 - East South Central	17.62
CD 7 - West South Central (excludes TX)	16.24
CD 8 - Mountain	13.19
CD 9 - Pacific (excludes CA)	13.58
CD 10 - New York	18.30
CD 11 - California	13.04
CD 12 – Texas	16.02
CD 13 – Florida	21.80
CD 14 – United States	15.56

8.5.2 Residential Electricity Prices

DOE derived 2008 annual electricity prices from EIA Form 861 data and 2008 monthly electricity prices from EIA Form 826. The EIA Form 861 data are published annually and include annual electricity sales, revenues from electricity sales, and number of consumers, for the residential, commercial, and industrial sectors at the utility level.[13] DOE calculated annual regional electricity prices by weighting each utility's average price by the number of electricity consumers in each utility's service area. The EIA Form 826 data include monthly electricity sales, revenue from electricity sales, and electricity prices for each State.[14] DOE calculated monthly regional electricity prices by weighting the simple average of monthly electricity prices by the number of residential electricity consumers in each State.[15] Finally, DOE aggregated the prices by the nine U.S. Census Divisions and four large states.

Table 8.5.2 displays the 2008 annual and monthly electricity prices. As it did for natural gas, DOE used the monthly average electricity prices for the water heater analysis, but used annual weighted prices for direct heating equipment and pool heaters.

Table 8.5.2 Average Residential Electricity Prices in 2008

Geographic Area	**Annual Average** *(2009$/kWh)*	**Monthly Average** *(2009$/kWh)*
CD 1 - New England	0.175	0.174
CD 2 - Middle Atlantic (excludes NY)	0.130	0.131
CD 3 - East North Central	0.105	0.106
CD 4 - West North Central	0.087	0.088
CD 5 - South Atlantic (excludes FL)	0.102	0.103
CD 6 - East South Central	0.093	0.092
CD 7 - West South Central (excludes TX)	0.096	0.096
CD 8 - Mountain	0.098	0.098
CD 9 - Pacific (excludes CA)	0.103	0.104
CD 10 - New York	0.182	0.186
CD 11 - California	0.138	0.143
CD 12 - Texas	0.130	0.128
CD 13 - Florida	0.116	0.116
CD 14 - United States	0.117	0.118

8.5.3 Residential Oil Prices

DOE collected 2008 oil prices from EIA's Petroleum Navigator,[16] which includes monthly oil prices for residential, commercial, industrial, and transportation consumers by Petroleum Administration for Defense Districts (PADD). The first four PADD follow the U.S. Census Divisions. However, Arizona is not included in the PADD for the Pacific Region and New Mexico is excluded altogether. In addition, data was not provided for the East South Central region, West South Central region, Florida, Texas, and California, so national averages were used for these regions. DOE weighted the average residential oil prices for each PADD by the amount of oil consumed in each PADD.[17] DOE then transformed the data in units of cents/gallon to $/MMBtu. Finally, the prices were aggregated and averaged by nine geographic areas (Table 8.5.3). The EIA oil price data do not include taxes, so DOE determined the average tax rate for the four Census Regions (Northeast, South, Midwest, and West)[18] and applied it to the annual average data.

Table 8.5.3 Average Monthly Residential Oil Prices in 2008

Geographic Area	Monthly Average *(2009$/MMBtu)*
CD 1 - New England	24.17
CD 2 - Middle Atlantic (excludes NY)	24.78
CD 3 - East North Central	23.56
CD 4 - West North Central	23.48
CD 5 - South Atlantic (includes FL)	24.13
CD 6 - East South Central*	23.89
CD 7 - West South Central *	24.09
CD 8 - Mountain	23.86
CD 9 - Pacific (includes CA)	24.79
CD 10 - New York	24.61
CD 11 – California**	25.62
CD 12 - Texas*	24.60
CD 13 - Florida***	24.24
CD 14 - United States	24.27

*National average
**Pacific Division average
***South Atlantic Division average

8.5.4 Residential LPG Prices

DOE collected 2007 average LPG prices from EIA's 2007 State Energy Consumption, Price, and Expenditures Estimates (SEDS).[19] SEDS includes annual LPG prices for residential, commercial, industrial, and transportation consumers by State. DOE weighted the average residential LPG prices for each State by the amount of LPG consumed by each State. Finally, DOE aggregated and averaged the prices by 13 geographic areas (Table 8.5.4).

Table 8.5.4 Average Residential LPG Prices in 2007

Geographic Area	Annual Average *(2009$/MMBtu)*
CD 1 - New England	30.14
CD 2 - Middle Atlantic (excludes NY)	30.32
CD 3 - East North Central	23.60
CD 4 - West North Central	20.89
CD 5 - South Atlantic (excludes FL)	28.18
CD 6 - East South Central	27.11
CD 7 - West South Central (excludes TX)	24.41
CD 8 – Mountain	25.04
CD 9 - Pacific (excludes CA)	29.28
CD 10 - New York	29.56
CD 11 – California	30.66
CD 12 – Texas	27.55
CD 13 – Florida	33.49
CD 14 - United States	26.19

8.5.5 Energy Price Trends

DOE used price forecasts from EIA's *Annual Energy Outlook 2010* (*AEO2010)*[20] to estimate the trends in natural gas, electricity, oil and LPG prices. To project future prices, DOE multiplied the average prices described in the preceding section by the forecast of annual average price changes in *AEO2010*. To estimate the trend after 2035, DOE used the average rate of change during 2025–2035 for electricity and the average rate of change during 2020–2035 for natural gas, LPG and oil.

DOE calculated LCC and PBP using three separate projections from *AEO2010*: Reference, Low Economic Growth, and High Economic Growth. These three cases reflect the uncertainty of economic growth in the forecast period. The high and low growth cases show the projected effects of alternative growth assumptions on energy prices. Figure 8.5.1 through Figure 8.5.4 show the residential electricity, natural gas, oil and LPG price trends, respectively. For the results presented in this chapter, DOE used only the energy price forecasts from the *AEO2010* Reference case.

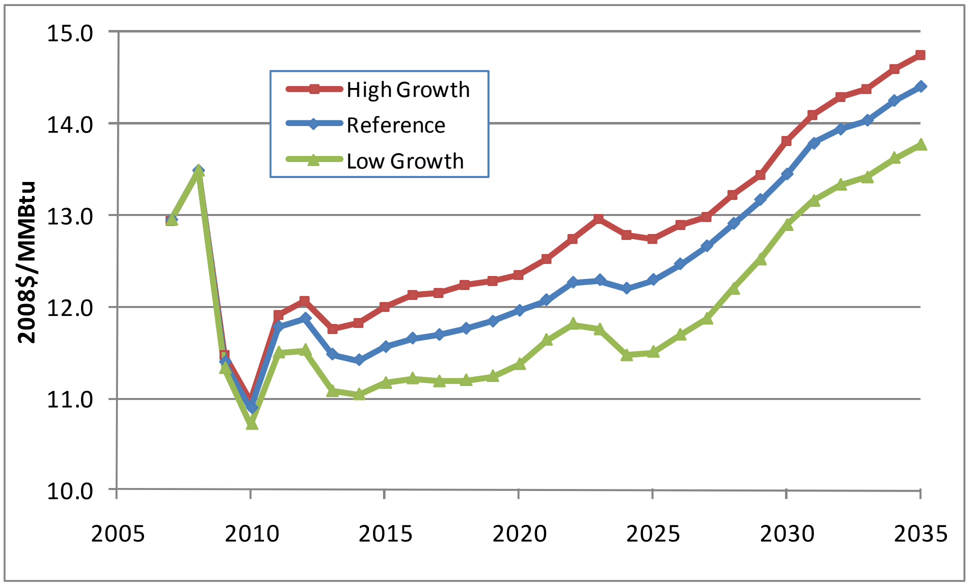

Figure 8.5.1 Residential Natural Gas Price Trends in AEO2010

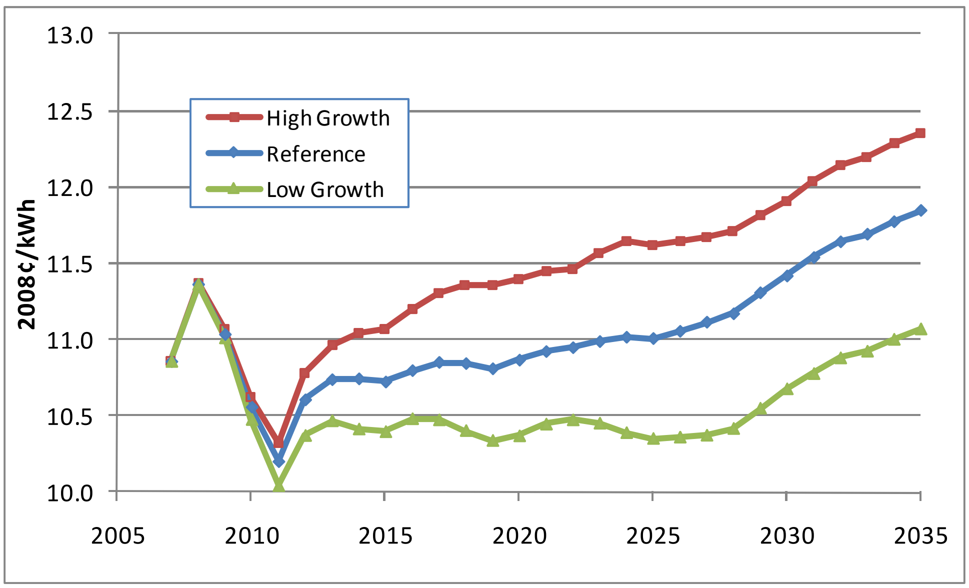

Figure 8.5.2 Residential Electricity Price Trends in AEO2010

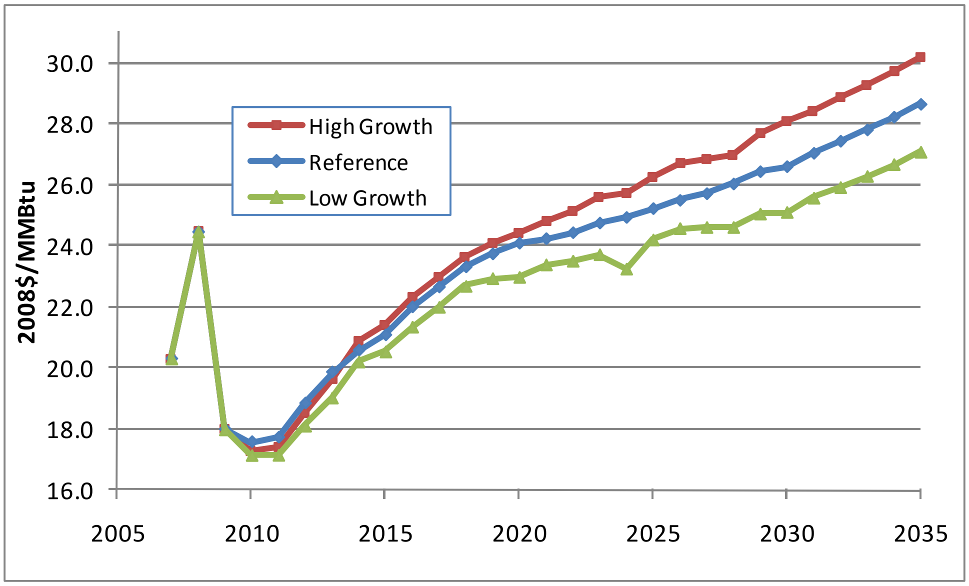

Figure 8.5.3 Residential Oil Price Trends in AEO2010

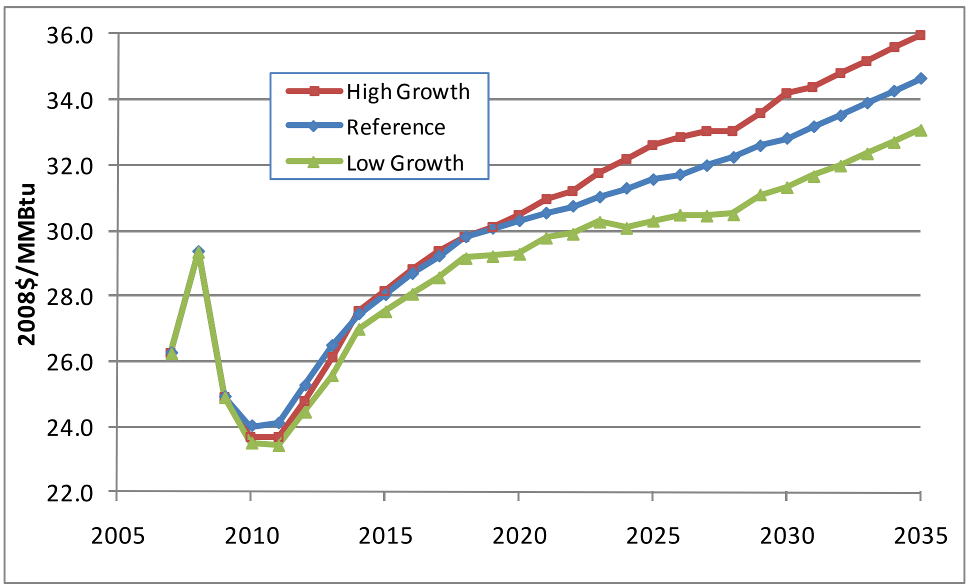

Figure 8.5.4 Residential LPG Price Trends in AEO2010

8.6 MAINTENANCE AND REPAIR COSTS

The maintenance cost is the cost of regular scheduled product maintenance. The repair cost is the cost to repair the product when it fails. These costs cover all labor and material costs associated with the maintenance or repair. The determination of the repair cost involves determining the cost and the service life of the components that are likely to fail. The component lifetime is presented as a distribution. This section provides a summary of DOE’s estimation of maintenance and repair costs for water heaters, direct heating equipment, and pool heaters; appendix 8-B provides the details and results.

8.6.1 Water Heaters

8.6.1.1 Gas-Fired Storage Water Heaters

Manufacturers recommend that storage water heaters be drained and flushed annually to minimize deposition of sediment, maintain operating efficiency, and prolong product life. The available evidence indicates that this practice is done in 10 percent of households, and mostly in locations with hard water.[21] DOE assumed that, of this 10 percent, only 25 percent of consumers hire a contractor to perform the maintenance work. For this maintenance cost, the labor hours were determined from a consultant's report,[21] and the labor cost is based on RS Means.[8, 22] The total cost of $110 per year is applicable to 2.5 percent of installations.

In addition, all new gas-fired storage water heaters are equipped with Flammable Vapor Ignition Resistant (FVIR), which manufacturers recommend be maintained annually. The available evidence indicates that 25 percent of households are likely to hire a contractor to perform this work.[23] For this maintenance cost, the labor hours are determined from a consultant's repor,[21] and the labor cost is based on RS Means.[8, 22] The total cost of $146 per year is applicable to 25 percent of installations.

The repair cost reflects the cost for a service call when the product fails. In some cases, if a gas-fired water heater fails, residential consumers tend to replace the unit rather than having it repaired. However, there are four design options considered for the gas-fired water heater analysis that may encounter repair cost during the lifetime of the water heater: pilot ignition, electronic ignition, power vent, and condensing design. The efficiency levels that include power vent or condensing design encounter both power vent as well as electronic ignition repair costs.

DOE estimated that the repair cost for the pilot ignition, a design option associated with the baseline water heater, is $246, and that such replacement occurs at most once, on average in the tenth year of the product lifetime.[6, 24] DOE estimated that the repair cost for the electronic ignition (hot surface type) is $293, and that such replacement occurs at most once, on average in the fifteenth year of the product lifetime.[6, 24] The repair cost of the power vent represents the cost of replacing the fan. DOE estimated that the average fan repair cost is $361, and that the power vent fan fails on average in the fifteenth year of operation.[24]

8.6.1.2 Electric Storage Water Heaters

Manufacturers recommend that electric storage water heaters be drained and flushed annually to minimize deposition of sediment, maintain operating efficiency, and prolong product life. The available evidence indicates that this practice is done in 10 percent of households, mostly in locations with hard water.[21] DOE assumed that of this 10 percent fraction only 25 percent hire a contractor to due the maintenance work. For this maintenance cost, labor hours and costs are based on RS Means[8, 22] and are equal to $110 per year for 2.5 percent of the installations.

For a heat pump water heater, maintenance includes annual cleaning of the air filter and a preventative maintenance cost to check the evaporator and refrigeration system. The literature recommends that professional help is not needed for this maintenance.[25, 26] However, DOE accounted for instances in which such help may be needed by adding a preventative maintenance cost for certain heat pump water heater installations to check the evaporator and refrigeration system. For locations where the heat pump water heater might be more exposed to the outdoor environment, such as garages and crawlspaces, DOE applied a 5-year preventative maintenance cost based on Australian heat pump water heater outdoor installations.[27, 28] DOE estimated that 27 percent of these exposed installations would require this maintenance, based on a survey conducted for central air conditioners.[29] For this maintenance cost, labor hours and costs are based on RS Means[8, 22] and are equal to about $84. For heat pump water heaters that are located indoors or in basements, the maintenance requirements are considered to be the same as other similar indoor appliances such as refrigerators and room heaters, which don't have any additional maintenance costs.[6, 30]

The repair cost for electric water heaters includes the cost of replacing the heating element. Based on available information, DOE estimated that the heating element fails on average in the fifth year of operation[f] for 20 percent of the households.[21] The estimated average heating element repair cost is $110.

The repair cost for the heat pump water heater represents the cost of replacing the compressor and the evaporator fan where necessary. Based on available information,[30, 31] DOE used a lifetime distribution for the compressor and evaporator fan with an average of 19 years. Although the average lifetime used for heat pump water heaters is 13 years, the lifetime distribution for the compressor and evaporator fan overlaps with the lifetime distribution for heat pump water heaters. Thus, some units are expected to receive this repair cost. The estimated average compressor repair cost is $294 and the estimated average fan repair cost is $130.

8.6.1.3 Oil-Fired Storage Water Heaters

Oil-fired storage water heaters and burners are cleaned and maintained regularly. Maintenance is most frequently performed under annual maintenance contracts, which typically includes repair of failed components. These contracts are very common in the northeast, where most of the oil-fired heating products are located.

DOE estimated the average cost of separate maintenance/repair contracts only for water heaters as $153 per year. This mean value comes from a collection of annual maintenance contract prices, which were gathered from web sites that represent oil-fired product suppliers in the eastern U.S. This cost varies, depending on the presence of other oil-fired products in the residence (see appendix 8-B). Costs may go down if multiple oil-fired appliances in a household are on the same contract. The maintenance contracts apply to all efficiency levels.

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[f] DOE used a triangular distribution with a mean of 5 years and a maximum of 9 and minimum of 1 year.

In addition to the items included in the maintenance contract, DOE determined that the manufacturers recommended draining and flushing, which is not included in the maintenance agreements. Therefore, this cost was added similarly as it was to electric and gas-fired storage water heaters.

8.6.1.4 Gas-Fired Instantaneous Water Heaters

Gas-fired instantaneous water heaters may incur maintenance costs for addressing the fouling of the heat exchanger from hard water, periodic sensor inspections and filter changes. All manufacturers recommend that these water heaters be de-limed annually to minimize deposition of sediment, maintain operating efficiency and prolong product life. DOE's analysis used an average maintenance cost of $110 per year for all energy efficiency levels of instantaneous water heaters.[5, 32] DOE assumed that the de-liming maintenance would apply to 75 percent of households (those without soft water or water softener) and that of these households, 75 percent would call a contractor to complete the work. Therefore, 56 percent of all households would encounter this maintenance cost.

The repair cost for gas-fired instantaneous water heaters is similar to the cost for gas-fired storage water heaters. Design options that may encounter repair cost during the lifetime of the water heater include pilot ignition, electronic ignition, and inducer fan. DOE estimated that the average repair cost for the pilot ignition, a design option associated with the baseline design, is $167, and that such replacement occurs at most once, on average in the tenth year of the product lifetime.[6, 33] It estimated that the average repair cost for the electronic ignition is $211, and that such replacement occurs at most once, on average in the tenth year of the product lifetime.[6, 33] The repair cost for the inducer fan represents the cost of replacing the fan. The estimated average fan repair cost is $304, with fan failure occurring on average in the fifteenth year of operation.[33]

The efficiency levels that include inducer fan or condensing design encounter inducer fan as well as electronic ignition repair cost.

8.6.2 Direct Heating Equipment

For direct heating equipment, DOE used the maintenance cost data from the 2007 furnace/boiler rulemaking.[3] The costs were derived from a field survey sponsored by several gas utilities that repair and service furnace and boiler equipment. The survey estimated the average cost per service call as the average total service charge (parts, labor, and other charges), which DOE estimated to be $222. DOE used a maintenance frequency of once every five years for all direct heating equipment products.

DOE determined the repair cost using an approach that reflects the cost and the service life of the components that are likely to fail. Designs considered for the direct heating equipment analysis that may incur repair costs during the lifetime of the product include pilot ignition, electronic ignition, circulating blower, and induced draft fan. DOE estimated that the repair cost for the pilot ignition is $174 for gas wall fan DHE and gas wall gravity DHE, $146 for gas room DHE and $157 for gas hearth DHE, and that such replacement occurs at most once, on average in the tenth year of the product lifetime.[6, 33] It estimated that the repair cost for the electronic ignition equals $220 for gas wall fan DHE and gas wall gravity DHE, $184 for gas room DHE and $198 for gas hearth DHE, and that such replacement occurs at most once, on average in the tenth year of the product lifetime.[6, 33] The repair cost of the air circulation blower represents the cost of replacing the fan. DOE estimated the average fan repair cost to be $319 for gas wall fan DHE and gas wall gravity DHE, $268 for gas room DHE and $288 for gas hearth DHE, with blower fan failure on average in the 12th year of operation.[33] DOE estimated the average repair cost of the induced draft fan to be $319 for gas wall fan DHE and 288 for gas hearth DHE, with fan failure on average in the fifteenth year of operation.[33]

The average repair cost of the condensing design includes electronic ignition, circulation blower and induced draft components.

8.6.3 Gas-Fired Pool Heaters

Pool owners typically do not regularly maintain pool heaters. However, when a pool heater stops working, maintenance work includes checking controls, cleaning burners, cleaning the heat exchanger, starting the heater and measuring water temperature rise. This amounts to an average cost of $316. For power vent and condensing design options, maintenance also includes measuring combustion differential pressure, which yields an average maintenance cost of $457. DOE estimated that, on average, both of these maintenance costs occur in the fifth year of the pool heater lifetime.[34]

Design options considered that may encounter repair cost during the lifetime of the pool heater include pilot ignition, electronic ignition, and power vent. DOE estimated that the average repair cost for the pilot ignition is $145, and that replacement occurs at most once, on average in the tenth year of the product lifetime.[6, 33] It estimated that the repair cost for the electronic ignition is $213, and that replacement occurs at most once, on average in the fifteenth year of the product lifetime.[6, 33] DOE estimated that the repair cost of the power vent includes replacing the fan at an average cost of $368, with estimated product failure on average in the fifteenth year of operation.[33] The efficiency levels that include power vent or condensing design encounter both power vent as well as electronic ignition repair cost.

8.7 PRODUCT LIFETIME

The product lifetime is the age at which the product is retired from service. This section details how DOE developed lifetime distributions for each of the three heating products.

8.7.1 Water Heaters

Table 8.7.1 presents the sources found by DOE to provide estimates of the lifetime of water heaters. The available information suggests that LPG storage water heaters have a lifetime equivalent to that of gas-fired storage water heaters.

Table 8.7.1 Water Heaters: Product Lifetime Estimates and Sources

Typical Lifetime or Range (years)	Source
Gas-Fired Storage	
13	U.S. Department of Energy[35]
11 to 13	National Association of Home Builders[36]
13	American Council for an Energy Efficient Economy [37]
Average =11; Low = 7; High = 15	*Appliance* magazine[31]
5 to 13	Residential Water Heaters Final Rule 2001[38]
13	DEER[39]
Electric Storage	
13	U.S. Department of Energy[35]
14	National Association of Home Builders[36]
13	American Council for an Energy Efficient Economy[37]
Average = 13; Low = 4; High = 20	*Appliance* magazine[31]
6 to 21	Residential Water Heaters Final Rule 2001[38]
15	DEER[39]
Oil-Fired Storage	
8	American Council for an Energy Efficient Economy[37]
5 to 13	Residential Water Heaters Final Rule 2001[38]
Gas-Fired Instantaneous	
20	DEER[39]
20	Low Energy Systems[40]
20+	National Association of Home Builders [41]
15 to 20	Builders Websource[42]

In its pre-NOPR analysis for gas-fired and electric storage water heaters, DOE chose averages based on the values in the middle of the range for the identified sources: 12 years for gas and 14 years for electric. In the NOPR analysis, DOE found that applying the above values to historic shipments (as discussed in chapter 9) resulted in estimates of the stock of gas-fired and electric storage water heaters that did not match the data on the stock reported in the 2007 American Housing Survey (AHS), which covers all housing units in the United States.[43] The estimated stock is too low for gas-fired storage water heaters and too high for electric storage water heaters. The implication is that the lifetimes used (average of 12 years for gas and 14 years for electric) are incorrect. Using an average lifetime of 13 years for both gas-fired and electric storage water heaters results in stock estimates for 2007 that are close to the stock numbers from the AHS. Therefore, DOE used an average lifetime of 13 years for both gas-fired and electric storage water heaters in its NOPR analysis, along with a minimum value of 6 years and a maximum value of 20 years.

For oil-fired storage water heaters, DOE utilized the approach from the 2001 water heater rulemaking[4] and assumed that these water heaters have the same distribution of lifetimes as gas-fired storage water heaters.

For gas-fired instantaneous water heaters, local variables such as water quality, humidity and maintenance schedules all influence the predicted lifetime. DOE used 20 years as the average lifetime based on the estimates in Table 8.7.1, with a range from 8 to 30 years.

Table 8.7.2 shows the average, minimum and maximum lifetime values used in the LCC analysis. For each product class, DOE characterized the product lifetime using a Weibull probability distribution that ranged from the minimum to maximum lifetime estimates shown in the table.

DOE evaluated whether electric heat pump water heaters have a different lifetime from the baseline products. An accelerated durability test of heat pump water heaters conducted by Oak Ridge National Laboratory suggests that these units have similar lifetime as standard electric resistance storage water heaters.[44] Therefore, DOE used the same lifetime distribution for all efficiency levels considered for this product class, as well as for the other product classes.[g]

Table 8.7.2 Water Heaters: Average, Minimum, and Maximum Product Lifetimes Used in LCC Analysis

Product Class	**Minimum** *years*	**Average** *years*	**Maximum** *years*
Gas-Fired/LPG Storage	6	13	20
Electric Storage	6	13	20
Oil-Fired Storage	6	13	20
Gas-Fired Instantaneous	8	20	30

8.7.2 Direct Heating Equipment

Limited information is available on the lifetime of direct heating equipment. Therefore, DOE used the average, minimum and maximum lifetime values from the 1993 TSD, p.1-45,[6] as shown in Table 8.7.3. DOE characterized the product lifetime using a Weibull probability distribution that ranged from the minimum to maximum lifetime.[45]

[g] Some advanced water heater designs may apply design options that effectively increase or decrease the lifetime of the product. For example, gas-fired water heater designs that utilize electricity may incorporate electrical anodes that may prolong the lifetime of the water heater heat exchanger. However, DOE had insufficient information to incorporate a different lifetime for water heaters at different efficiency levels.

Table 8.7.3 Direct Heating Equipment: Average, Minimum, and Maximum Product Lifetimes Used in LCC Analysis

Product Class Category	Minimum *years*	Average *years*	Maximum *years*
Gas Wall Fan DHE	10	15	20
Gas Wall Gravity DHE	10	15	20
Gas Floor DHE	10	15	20
Gas Room DHE	10	15	20
Gas Hearth DHE	10	15	20

8.7.3 Gas-Fired Pool Heaters

Table 8.7.4 presents the sources found by DOE to provide estimates of the lifetime of gas-fired pool heaters. The available information suggests that LPG-fired pool heaters have a lifetime equivalent to that of gas-fired pool heaters.

Table 8.7.4 Gas-Fired Pool Heaters: Product Lifetime Estimates and Sources

Typical Lifetime (years)	Source
5	U.S. Department of Energy: Energy Efficiency and Renewable Energy[46]
5	Illinois Propane Gas Association[47]
6	Pool Quest[48]
10*	The Spa Specialist Inc.[49]

* Refers to spa heaters.

Based on the information collected, results from the shipments model and a consultant report,[50] DOE used eight years for average lifetime of gas-fired pool heaters, and estimated minimum and maximum lifetime values of three and 20 years (Table 8.7.5). The consultant report indicated that many factors impact pool heater lifetimes, resulting in a large range of lifetime values depending on location. Factors including wind, humidity, pressure, frequency of use and temperature all affect the lifetime of a pool heater. DOE characterized the product lifetime using a Weibull probability distribution that ranged from the minimum to maximum lifetime estimates.

Table 8.7.5 Gas-Fired Pool Heaters: Average, Minimum, and Maximum Product Lifetimes Used in LCC Analysis

Minimum *(years)*	Average *(years)*	Maximum *(years)*
3	10	20

8.8 DISCOUNT RATES

The discount rate is the rate at which DOE discounted future expenditures to establish their present value. DOE derived the discount rates for the LCC and PBP analyses from estimates of the finance cost of purchasing the considered products. Following financial theory, the finance cost of raising funds to purchase appliances can be interpreted as: (1) the financial cost of any debt incurred to purchase products, or (2) the opportunity cost of any equity used to purchase products. The financing of purchasing products installed in new homes is different than the financing of appliances bought directly by consumers (e.g., for replacement). Thus, DOE used different discount rates for these applications.

8.8.1 Discount Rate for Replacement Products Purchased by Consumers

Households use a variety of methods to finance purchase of major appliances. In principle, it is possible to estimate the interest rates on the actual financing vehicles used to purchase appliances. However, the shares of different financing vehicles in total appliance purchases are unknown.

DOE's approach involves identifying all possible debt or asset classes that might be used to purchase the considered appliances, including household assets that might be affected indirectly.[h] DOE did not include debt from primary mortgages and equity of assets considered non-liquid (such as retirement accounts), since these would likely not be affected by appliance purchases. DOE estimated the average shares of the various debt and equity classes in the average U.S. household equity and debt portfolios using data from the Federal Reserve Board's *Survey of Consumer Finances (*SCF*)* for 1989, 1992, 1995, 1998, 2001, 2004, and 2007.[51] Table 8.8.1 shows the average shares of each considered class. DOE used the mean share of each class across the seven surveys as a basis for estimating the weight of the classes in the direct or indirect financing of the considered appliances.

[h] An indirect effect would arise if a household sold some assets in order to pay off a loan or credit card debt that might have been used to finance the actual appliance purchase.

Table 8.8.1 Average Shares of Considered Household Debt and Equity Classes

	1989 SCF	1992 SCF	1995 SCF	1998 SCF	2001 SCF	2004 SCF	2007 SCF	Mean (%)
Home equity loans	4.3	4.5	2.7	2.8	2.8	4.4	4.6	3.7
Credit cards	1.6	2.1	2.6	2.2	1.7	2.0	2.4	2.1
Other installment loans	2.8	1.7	1.4	1.7	1.1	1.3	1.1	1.6
Other residential loans	4.4	6.9	5.2	4.3	3.1	5.8	7.1	5.3
Other line of credit	1.1	0.6	0.4	0.2	0.3	0.5	0.3	0.5
Checking accounts	5.8	4.7	4.9	3.9	3.6	4.2	3.4	4.4
Savings & money market	19.2	18.8	14.0	12.8	14.2	15.1	13.0	15.3
Certificate of deposit (CD)	14.5	11.7	9.4	7.0	5.4	5.9	6.5	8.6
Savings bond	2.2	1.7	2.2	1.1	1.2	0.9	0.7	1.4
Bonds	13.8	12.3	10.5	7.0	7.9	8.4	6.7	9.5
Stocks	22.4	24.0	25.9	36.9	37.5	28.0	28.6	29.0
Mutual funds	8.0	11.1	20.9	20.1	21.3	23.4	25.5	18.6
Total	100	100	100	100	100	100	100	100

Table 8.8.2

DOE estimated interest or return rates associated with each type of equity and debt. The data source for the interest rates for loans, credit cards, and lines of credit is the Federal Reserve Board's SCF in 1989, 1992, 1995, 1998, 2001, 2004, and 2007. Table 8.8.3 shows the average nominal rates in each year, and the inflation rates used to calculate real rates. For home equity loans, DOE calculated effective interest rates in a similar manner as for mortgage rates, since interest on such loans is tax deductible. Table 8.8.4 shows the average effective real rates in each year and the mean rate across the years. Since the interest rates for each debt carried by households in these years were established over a range of time, DOE believes they are representative of rates that may apply when amended standards take effect.

Table 8.8.3 Average Nominal Interest Rates for Household Debt Classes (percent)

	1989 SCF	1992 SCF	1995 SCF	1998 SCF	2001 SCF	2004 SCF	2007 SCF	Mean (%)
Home equity loans	11.5	9.6	9.6	9.8	8.7	5.7	7.9%	9.0%
Credit cards*	-	-	14.2	14.5	14.2	11.7	12.6%	13.4%
Other installment loans	9.0	7.8	9.3	7.8	8.7	7.4	10.4%	8.6%
Other residential loans	8.8	7.6	7.7	7.7	7.5	6.0	6.3%	7.4%
Other line of credit	14.8	12.7	12.4	11.9	14.7	8.8	12.7%	12.6%
Inflation rate	4.82	3.01	2.83	1.56	2.85	2.66	2.85	

* No interest rate data available for credit cards in 1989 or 1992.

Table 8.8.4 Average Real Effective Interest Rates for Household Debt Classes (percent)

	1989 SCF	1992 SCF	1995 SCF	1998 SCF	2001 SCF	2004 SCF	2007 SCF)	Mean (%)
Home equity loans	3.8	4.3	4.4	5.8	3.8	1.9	3.3	3.9
Credit cards*	-	-	11.0	12.7	11.1	9.1	9.7	10.7
Other installment loans	4.9	5.8	7.0	6.6	6.1	5.4	5.8	6.0
Other residential loans	4.0	4.7	4.8	6.0	4.6	3.3	3.4	4.4
Other line of credit	9.6	9.4	9.3	10.2	7.3	6.0	9.7	8.8

* No interest rate data available for credit cards in 1989 or 1992.

DOE developed a probability distribution of interest rates for each debt class based on the *SCF* data. To account for variation among households, DOE sampled a rate for each household from the distributions for the appropriate debt class. Appendix 8-D presents the probability distributions for each class that DOE used in the LCC and PBP analyses.

Similar rate data are not available from the *SCF* for the asset classes, so DOE derived data for these classes from national-level historical data. The interest rates associated with certificates of deposit (CDs),[52] savings bonds,[53] and bonds (AAA corporate bonds)[54] are from Federal Reserve Board time-series data covering 1977–2008. DOE assumed rates on checking accounts to be zero. Rates on savings and money market accounts are from Cost of Savings Index data covering 1984–2008.[55] The rates for stocks are the annual returns on the Standard and Poor's (S&P) 500 in 1977–2008.[56] The mutual fund rates are a weighted average of the stock rates (two-thirds weight) and the bond rates (one-third weight) in each year of the 1977–2008 period. DOE adjusted the nominal rates to real rates using the annual inflation rate in each year. The average nominal and real interest rates for the classes of assets are shown in Table 8.8.5. Since the interest rates for each debt carried by households in these years were established over a range of time, DOE believes they are representative of rates that may apply when amended standards take effect.

Table 8.8.5 Average Nominal and Real Interest Rates for Household Equity Classes

	Average Nominal Rate (%)	Average Real Rate (%)
Checking accounts	-	0.0
Savings and money market	5.4	2.2
CDs	6.6	2.3
Savings bonds	7.7	3.3
Bonds	8.5	4.1
Stocks	11.6	7.1
Mutual funds	10.3	5.8

Table 8.8.6 summarizes the mean real effective rates of each type of equity or debt. DOE determined the average share of each debt and asset using *SCF* data for 1989, 1992, 1995, 1998, 2001, 2004, and 2007. Each year of SCF data provides the debt and asset shares for U.S.

households. DOE averaged the debt and asset shares over the six years of survey data to arrive at the shares shown in Table 8.8.6 below. The average rate across all types of household debt and equity, weighted by the shares of each class, is 4.8 percent.

Table 8.8.6 Shares and Interest or Return Rates Used for Household Debt and Equity Classes

	Average Share of Household Debt plus Equity (%)*	**Mean Effective Real Rate (%)****
Home equity loans	3.7	3.9
Credit cards	2.1	10.7
Other installment loans	1.6	6.0
Other residential loans	5.3	4.4
Other line of credit	0.5	8.8
Checking accounts	4.4	0.0
Savings and money market accounts	15.3	2.2
CDs	8.6	2.3
Savings bonds	1.4	3.3
Bonds	9.5	4.1
Stocks	29.0	7.1
Mutual funds	18.6	5.8
Total/Weighted-average discount rate	100	**4.8**

* Not including primary mortgage or retirement accounts.

** Adjusted for inflation and, for home equity loans, loan interest tax deduction.

DOE developed a normal probability distribution of interest rates for each asset type by using the mean value and standard deviation from the distribution. To account for variation among households, DOE sampled a rate for each household from the distributions for the appropriate asset class. Appendix 8-D presents the probability distributions for each class that DOE used in the LCC and PBP analyses.

8.8.2 Discount Rates for Appliances Installed in New Housing

Appliances installed in new homes ("new-housing appliances") are purchased as part of the home, which is almost always financed with a mortgage loan. DOE estimated discount rates for new-housing appliances using the effective real (after-inflation) mortgage rate for homebuyers. This rate corresponds to the interest rate after deduction of mortgage interest for income tax purposes and after adjusting for inflation (using the Fisher formula).[i] For example, a six-percent nominal mortgage rate has an effective nominal rate of 4.5 percent for a household at the 25-percent marginal tax rate. When adjusted for inflation of two percent, the effective real rate becomes 2.45 percent.

[i] Fisher formula is given by: Real Interest Rate = ((1 + Nominal Interest Rate) / (1 + Inflation Rate)) – 1.

The data source DOE used for mortgage interest rates is the SCF in 1989, 1992, 1995, 1998, 2001, 2004, and 2007.[51] Using the appropriate SCF data for each year, DOE adjusted the mortgage interest rate for each relevant household in the SCF for mortgage tax deduction and inflation (see Table 8.8.7). In cases where the effective interest rate is equal to or below the inflation rate (resulting in a negative real interest rate), DOE set the real effective interest rate to zero.

The average nominal mortgage rate carried by homeowners in these six years was 7.9 percent. Since the mortgage rates carried by households in these years were established over a range of time, DOE believes they are representative of rates that may apply when amended standards take effect. After adjusting for inflation and interest tax deduction, effective real interest rates on mortgages across the six surveys averaged 3.0 percent.

Table 8.8.7 Data Used to Calculate Real Effective Mortgage Rates

Year	**Average Nominal Interest Rate (%)**	**Inflation Rate[57] (%)**	**Marginal Tax Rate Applicable to Mortgage Interest[58] (%)**	**Average Real Effective Interest Rate (%)**
1989	9.7	4.82	24.3	2.4
1992	9.1	3.01	23.4	3.8
1995	8.2	2.83	24.1	3.3
1998	7.9	1.56	23.9	4.4
2001	7.6	2.85	22.9	2.9
2004	6.2	2.66	20.6	2.2
2007	6.3	2.85	21.6	2.1
Average	7.9			**3.0**

To account for variation among households, DOE sampled a rate for each household in the RECS samples from a distribution of mortgage rates. DOE developed the distribution based on the *SCF* data. Appendix 8-D presents the probability distribution that DOE used in the LCC and PBP analyses.

8.9 EFFECTIVE DATE OF ENERGY CONSERVATION STANDARDS

The effective date is the future date when a new energy conservation standard becomes operative. A final rule for the products being considered for this energy conservation standards rulemaking is scheduled for completion in 2010. Therefore, the effective date of any new energy conservation standards for these products will be three years after the final rule is published for gas-fired pool heaters and direct heating equipment (2013), and five years after the final rule is published for water heaters (2015). DOE calculated the LCC for all consumers as if they each would purchase a new product in the year the energy conservation standard takes effect.

8.10 PRODUCT ENERGY EFFICIENCY IN THE BASE CASE

For each product class, DOE analyzed a number of energy efficiency levels above the baseline energy efficiency level. However, some consumers already purchase products with energy efficiencies greater than the baseline levels. Thus, to accurately estimate the percentage of consumers that would be affected by a standard at a particular efficiency level, DOE took into account the distribution of product energy efficiencies that consumers are expected to purchase under the base case (i.e., the case without new energy conservation standards). In other words, rather than analyzing the impacts of a particular standard level assuming that all consumers will purchase products at the baseline level, DOE conducted the analysis by taking into account the breadth of product energy efficiencies that consumers are expected to purchase under the base case.

As noted in section 8.1.1, DOE's approach for conducting the LCC analysis for heating products relied on developing samples of households that use each of the products, and using a Monte Carlo simulation technique to perform the LCC calculations on the households in the sample. DOE assigned each household in the sample a unique product energy efficiency taken from the estimated base-case distribution of product energy efficiencies in the effective year. The energy efficiency distributions used for each heating product are presented below.

8.10.1 Water Heaters

To estimate the market shares of different water heater energy efficiency levels in the base case, DOE began with fractions based on data for recent years provided by AHRI.[59] Since these data did not cover all of the energy efficiency levels under consideration, DOE supplemented them with data on the number of water heater models at different energy efficiency levels, as given in the February 2010 AHRI directory for gas-fired storage water heaters, electric storage water heaters, and oil-fired storage water heaters[60] and the June 2009 FTC Directory and February 2010 CEC directory [61] for gas-fired instantaneous water heaters.

DOE then took account of the estimated market impact of the new ENERGY STAR criteria for water heaters.[62] Effective in 2010, the minimum efficiency for the ENERGY STAR designation will be 0.67 EF for non-condensing gas-fired storage water heaters, 0.80 EF for condensing gas-fired storage water heaters, and 2.0 EF for heat pump water heaters. For both condensing gas-fired storage water heaters and heat pump water heaters, DOE considered the market penetration goals set by the ENERGY STAR program. DOE estimated that heat pump water heaters would reach half of the program goal by 2015, or 5 percent market share. DOE estimated that condensing gas-fired storage water heaters would achieve only about one-fifth of the goal (1 percent), as there are currently no residential models available in the market.

For gas-fired instantaneous water heaters, DOE estimated that the base-case market shares in 2015 would be equivalent to current shares. In the case of this product, the majority of the current market (approximately 85 percent of shipments) is already at the ENERGY STAR level, so there is limited room for the shares of ENERGY STAR products to increase in the near future. For oil-fired storage water heaters, DOE also estimated that the market shares in 2015 would be equivalent to current shares, as there has been little change in the past decade.

Table 8.10.1 presents the market shares of the energy efficiency levels in the base case for the representative rated volume for the four water heater product classes that DOE considered. These market shares represent the products that households would purchase in the year 2015 in the absence of new energy conservation standards.

Table 8.10.1 Water Heaters: Base Case Energy Efficiency Market Shares in 2015*

Energy Efficiency Level	Gas-Fired Storage		Electric Storage		Oil-Fired Storage		Gas-Fired Instantaneous	
	EF	Market Share *(%)*	EF	Market Share *(%)*	EF	Market Share *(%)*	EF	Market Share *(%)*
Baseline	0.59	64%	0.90	29.8%	0.53	0%	0.62	1.0%
1	0.62	23%	0.91	16.8%	0.54	20%	0.69	3.0%
2	0.63	2%	0.92	11.2%	0.56	0%	0.78	1.0%
3	0.64	5%	0.93	26.1%	0.58	0%	0.80	5.1%
4	0.65	0%	0.94	7.5%	0.60	10%	0.82	54.5%
5	0.67	5%	0.95	3.7%	0.62	20%	0.84	2.0%
6	0.77	1%	2.00	4.0%	0.66	25%	0.85	4.0%
7			2.35	1.0%	0.68	25%	0.92	21.2%
8							0.95	12.1%
		100		100		100		100

* The values refer to the representative sizes for each product class: 40 gal for gas-fired storage, 50 gal for electric storage, 32 gal for oil-fired storage.

8.10.2 Direct Heating Equipment

Very little is known regarding the distribution of direct heating equipment energy efficiencies that consumers in the United States currently purchase. To estimate the market shares of different energy efficiency levels in the base case, DOE used data on the fraction of direct heating equipment models at different energy efficiency levels, as given in the February 2010 AHRI directory.[63] The market shares in Table 8.10.2 represent the products that households would purchase in the year 2013 in the absence of new energy conservation standards.

Table 8.10.2 Direct Heating Equipment: Energy Efficiency Market Shares in the Base Case

Energy Efficiency Level	Gas Wall Fan		Gas Wall Gravity		Gas Floor		Gas Room		Gas Hearth	
	AFUE *(%)*	Market Share *(%)*	AFUE *(%)*	Market Share *(%)*	AFUE *(%)*	Market Share *(%)*	AFUE *(%)*	Market Share *(%)*	AFUE *(%)*	Market Share *(%)*
Baseline	74	40.0%	64	25.0%	57	42.9%	64	25.0%	64	39.8%
1	75	6.7%	66	25.0%	58	57.1%	65	0.0%	67	36.5%
2	76	26.7%	68	12.5%			66	25.0%	72	23.2%
3	77	20.0%	71	37.5%			67	25.0%	93	0.6%
4	80	6.7%	72	0.0%			68	25.0%		
5							83	0.0%		
		100%		100%		100%		100%		100%

8.10.3 Gas-Fired Pool Heaters

Data on the distribution of gas-fired pool heater shipments by energy efficiency level are not available. To estimate the market shares of different energy efficiency levels in the base case, DOE used data on the fraction of gas-fired pool heater models at different energy efficiency levels given in the May 2009 FTC directory.[64] The market shares in Table 8.10.3 represent the products at each efficiency level that households would purchase in the year 2013 in the absence of new energy conservation standards by ignition type.

Table 8.10.3 Gas-Fired Pool Heaters: Energy Efficiency Market Share by Ignition Type in the Base Case

Energy Efficiency Level	Thermal Efficiency *(%)*	Market Share		
		Pilot Light *(%)*	Electronic Ignition *(%)*	Total *(%)*
Baseline	78	0.0	0.0	0.0
1	79	14.2	22.1	36.3
2	81	3.5	14.2	17.7
3	82	8.8	13.3	22.1
4	83	0.0	2.7	2.7
5	84	0.0	15.9	15.9
6	86	0.0	4.4	4.4
7	90	0.0	0.0	0.0
8	95	0.0	0.9	0.9
Total		26.5	73.5	100.0%

8.11 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

This section presents the LCC and PBP results for the three types of heating products. As discussed in section 8.1.1, DOE's approach for conducting the LCC analysis relied on developing samples of households that use each of the products. DOE also characterized the uncertainty of many of the inputs to the analysis with probability distributions. DOE used a Monte Carlo simulation technique to perform the LCC calculations on the households in the sample. For each set of sample households using the products in each product class, DOE calculated the average LCC and LCC savings and the median and average PBP for each of the potential standard levels.

DOE calculated LCC savings and PBPs at each efficiency level relative to the base case products that it assigned to the households. For some households, DOE assigned base case products that are more energy efficient than some of the standard levels. If a household was assigned a product energy efficiency that is greater than or equal to the energy efficiency of the standard level under consideration, the LCC calculation reveals that this household is not impacted by an increase in product energy efficiency that is equal to the standard level. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific standard level and the LCC of the baseline products.

In the subsections below, DOE presents figures showing the distribution of LCCs in the base case for each product class. Also presented for a specific standard level are figures showing the distribution of LCC impacts and the distribution of PBPs. The figures are presented as frequency charts that show the distribution of LCCs, LCC impacts, and PBPs with their corresponding probability of occurrence. DOE generated the figures for the distributions from a Monte Carlo simulation run based on 10,000 samples.

LCC and PBP calculations were performed 10,000 times on the sample of households established for each residential product. Each LCC and PBP calculation was performed on a single household that was selected from the sample. The selection of a household was based on its weight (i.e., how representative a particular household is of other households in the distribution). Each LCC and PBP calculation also sampled from the probability distributions that DOE developed to characterize many of the inputs to the analysis.

For each standard level, DOE calculated the share of households with a net LCC benefit, with a net LCC cost, and with no impact. DOE considered a household to receive no impact at a given standard level if DOE assigned it base case products that are the same as or are more energy efficient than the standard level. To illustrate the range of LCC and PBP impacts among the sample households, the sections below present figures that provide such information for each product class.

8.11.1 Water Heaters

8.11.1.1 Distributions of Impacts

Figure 8.11.1 through Figure 8.11.4 show the frequency charts for the base case LCC for the water heater product classes that DOE analyzed.

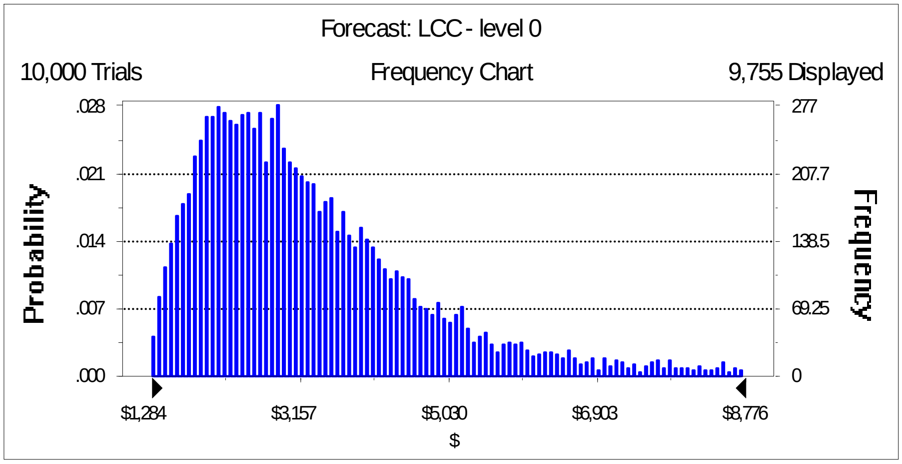

Figure 8.11.1 **Gas-Fired Storage Water Heaters: Base Case LCC Distribution**

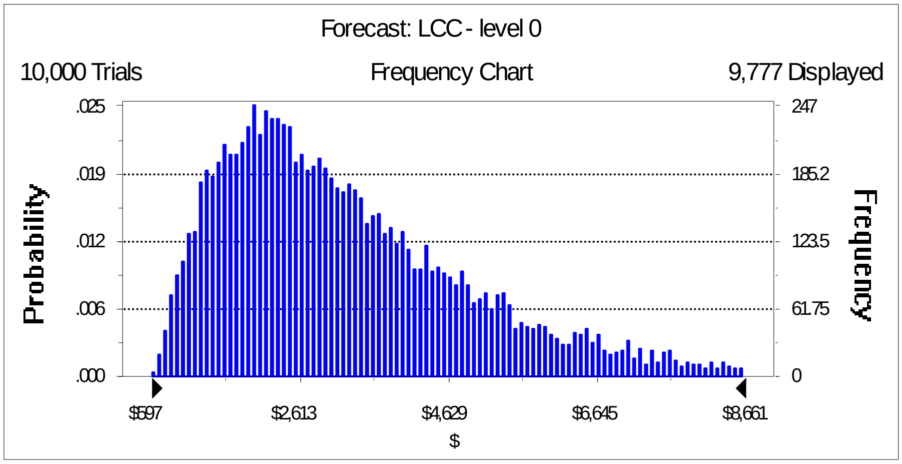

Figure 8.11.2 **Electric Storage Water Heaters: Base Case LCC Distribution**

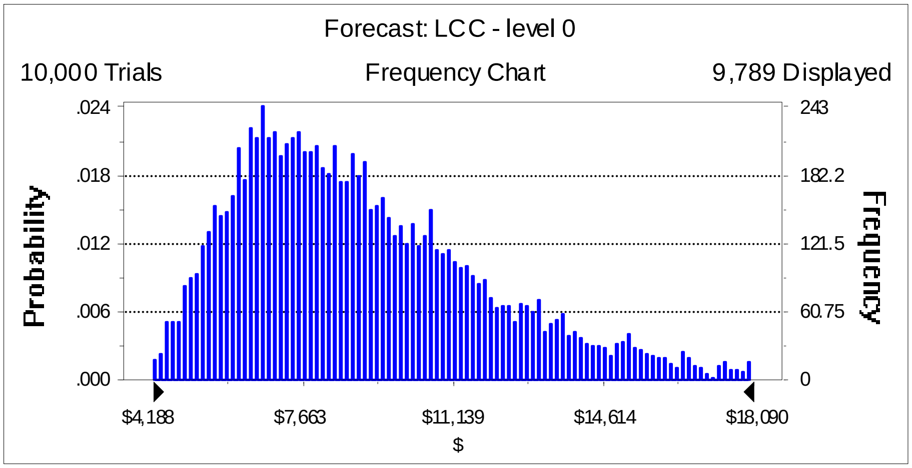

Figure 8.11.3 Oil-Fired Storage Water Heaters: Base Case LCC Distribution

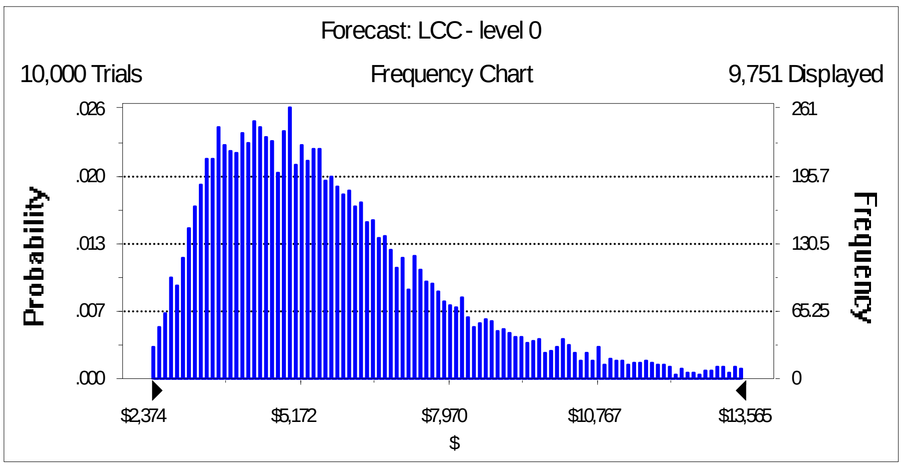

Figure 8.11.4 Gas-Fired Instantaneous Water Heaters: Base Case LCC Distribution

Figure 8.11.5 is an example of a frequency chart showing the distribution of LCC impacts for the case of Efficiency Level 2 for gas-fired storage water heaters. The large spike in the figure represents the percentage of households that are not impacted by an increase in the standard level, i.e., households that purchase gas-fired storage water heaters with energy efficiencies greater than or equal to the standard level. DOE can generate a frequency chart like the one shown in Figure 8.11.5 for every standard level. Figure 8.11.6 through Figure 8.11.8 are examples of frequency charts showing the distribution of LCC impacts selected efficiency levels for the other water heater product classes.

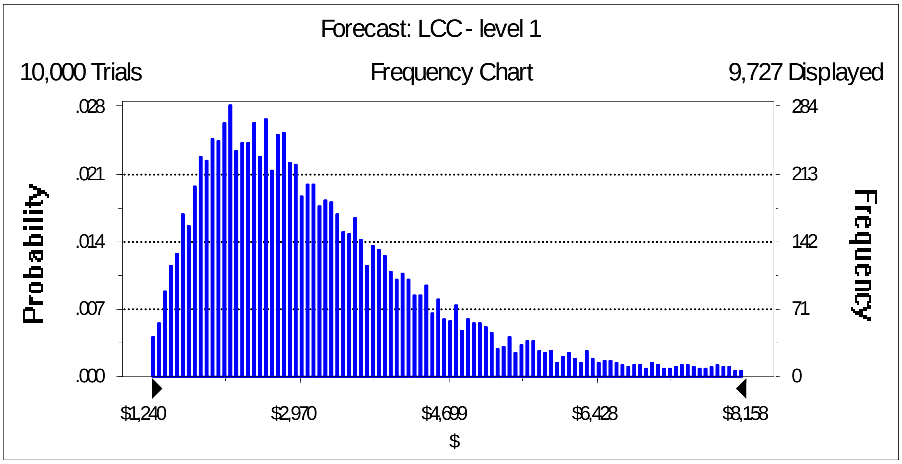

Figure 8.11.5 Gas-Fired Storage Water Heaters: Distribution of LCC Impacts for Efficiency Level 1

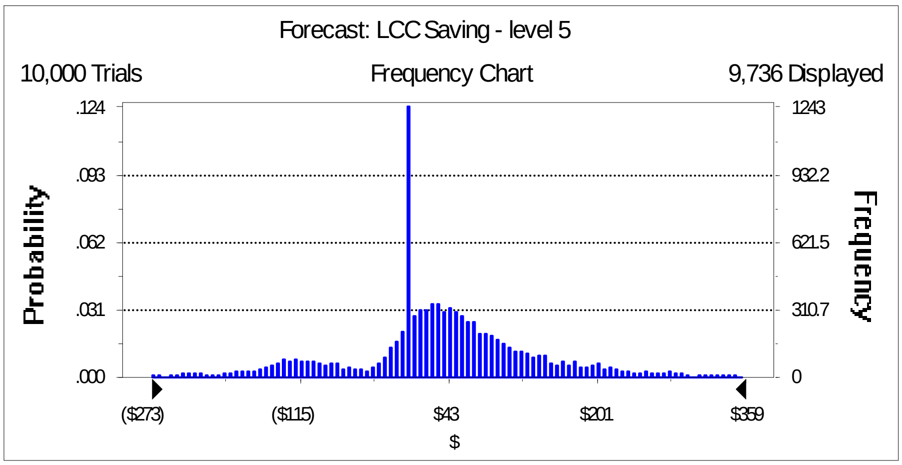

Figure 8.11.6 Electric Storage Water Heaters: Distribution of LCC Impacts for Efficiency Level 5

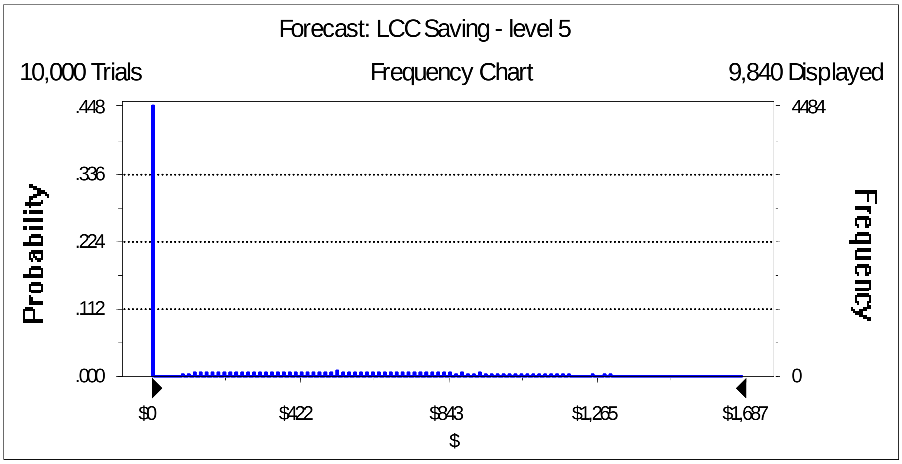

Figure 8.11.7 Oil-Fired Storage Water Heaters: Distribution of LCC Impacts for Efficiency Level 5

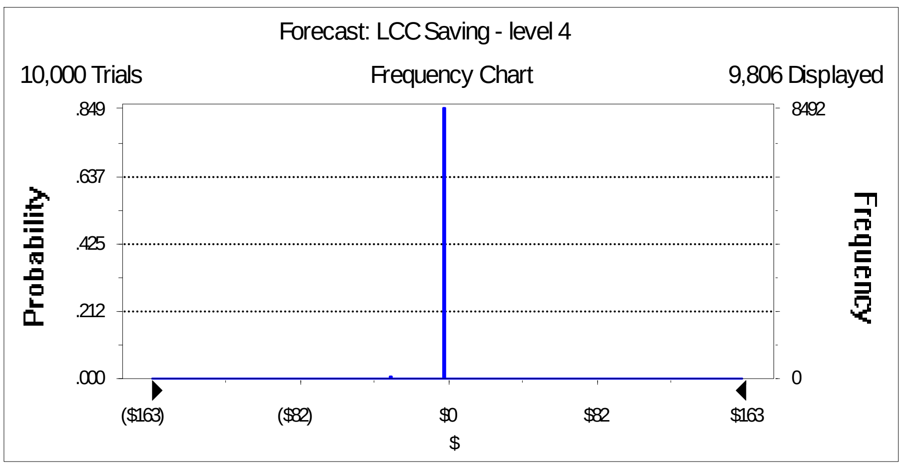

Figure 8.11.8 Gas-Fired Instantaneous Water Heaters: Distribution of LCC Impacts for Efficiency Level 4

Figure 8.11.9 is an example of a frequency chart showing the distribution of payback periods for Efficiency Level 2 for gas-fired storage water heaters. DOE can generate a frequency chart like the one shown in Figure 8.11.9 for every efficiency level within each product class. Figure 8.11.10 and Figure 8.11.12 are examples of frequency charts showing the distribution of payback periods for the other water heater product classes. The large spike at the left in Figure 8.11.12 indicates the percentage of households with gas-fired instantaneous water heaters that are not impacted by an increase in the standard level, i.e., households that already use gas-fired instantaneous water heaters with energy efficiencies equal to Efficiency Level 8.

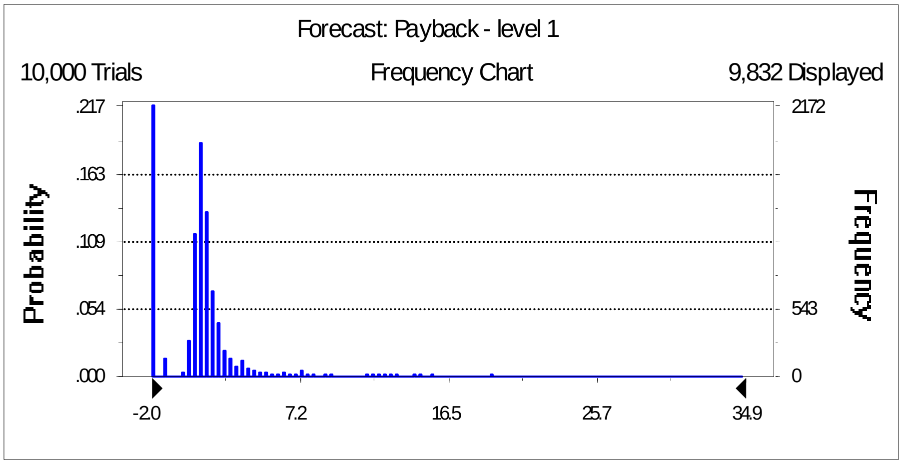

Figure 8.11.9 Gas-Fired Storage Water Heaters: Distribution of PBPs for Efficiency Level 1

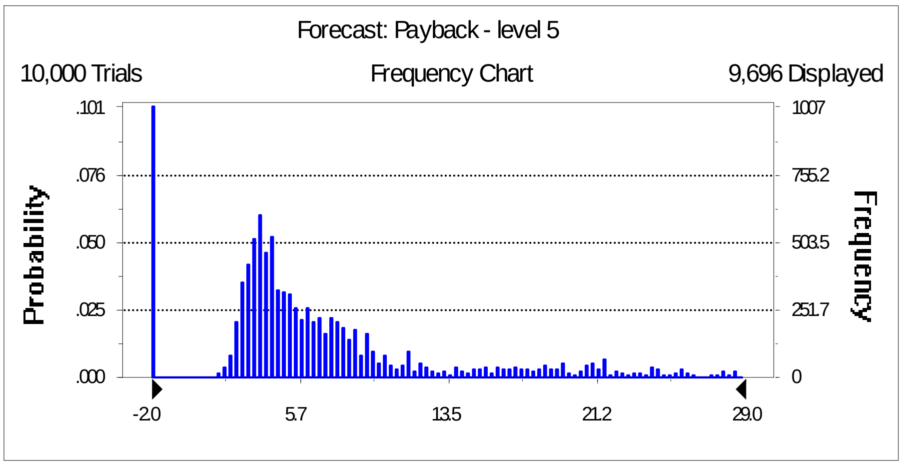

Figure 8.11.10 Electric Storage Water Heaters: Distribution of PBPs for Efficiency Level 5

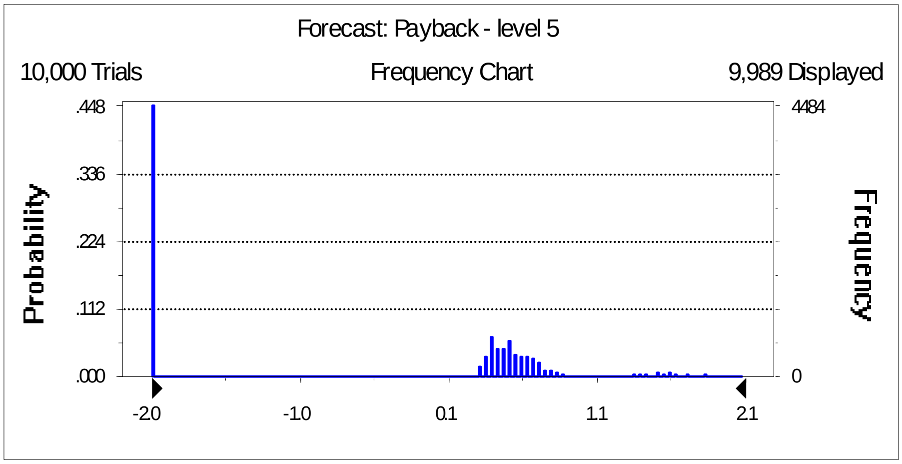

Figure 8.11.11 Oil-Fired Storage Water Heaters: Distribution of PBPs for Efficiency Level 5

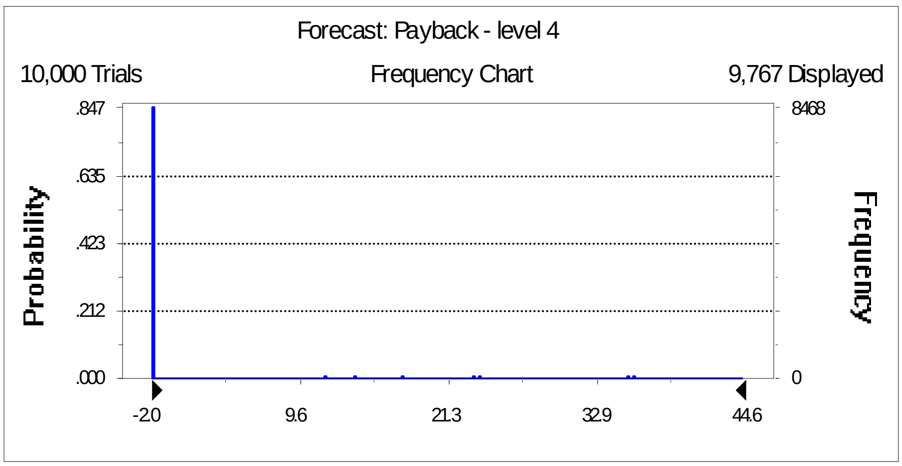

Figure 8.11.12 Gas-Fired Instantaneous Water Heaters: Distribution of PBPs for Efficiency Level 8

8.11.1.2 Summary of LCC and PBP Results

Table 8.11.1 through Table 8.11.4 summarize the LCC and PBP results for water heaters. As mentioned earlier, for some households, DOE assigned products in the base case that are more energy efficient than some of the energy efficiency levels under consideration. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific energy efficiency level and the LCC of the baseline product. Similarly with regard to the PBPs shown below, DOE determined the median and average values by excluding the percentage of households not impacted by a standard at a given efficiency level. The values for average lifetime operating cost in the tables are discounted sums of the annual operating costs over the product lifetime.

For gas-fired storage water heaters, Efficiency Level 1 (0.62 energy factor) has the highest average LCC savings and a median PBP of 2.0 years.[j] For electric storage water heaters, Efficiency Level 7 (2.35 energy factor) has the highest average LCC savings and a median PBP of 9.0 years. However, 50 percent of the households experience a net cost (i.e., negative savings). For oil-fired storage water heaters, Efficiency Level 7 (0.68 energy factor) has the highest average LCC savings and a median PBP of 1.9 years. For gas-fired instantaneous water heaters, Efficiency Level 2 (0.78 energy factor) has the highest average LCC savings and a median PBP of 6.1 years. Few households are impacted by a standard at this level, however, since most households have a unit with equal or higher efficiency in the base case.

Table 8.11.1 Gas-Fired Storage Water Heaters: LCC and PBP Results

Efficiency Level ID	Energy Factor	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*	
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact	Households with Net Benefit	Median	Average
Baseline	0.59	$1,079	$2,473	$3,552						
1	0.62	$1,171	$2,357	$3,528	$16	25%	36%	39%	2.0	17.0
2	0.63	$1,244	$2,293	$3,537	$7	32%	22%	45%	4.5	18.6
3	0.64	$1,559	$2,286	$3,845	-$267	72%	12%	16%	35.4	57.0
4	0.65	$1,591	$2,220	$3,812	-$235	70%	6%	23%	26.0	39.3
5	0.67	$1,656	$2,137	$3,793	-$218	70%	6%	23%	21.5	27.1
6	0.77	$1,893	$1,878	$3,771	-$195	70%	1%	28%	15.6	16.8

Table 8.11.2 Electric Storage Water Heaters: LCC and PBP Results

Efficiency Level ID	Energy Factor	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*	
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact	Households with Net Benefit	Median	Average
Baseline	0.90	$569	$2,703	$3,273						
1	0.91	$602	$2,667	$3,269	-$1	7%	68%	25%	3.8	11.8
2	0.92	$623	$2,632	$3,255	$5	11%	44%	45%	4.0	10.2
3	0.93	$634	$2,611	$3,245	$11	12%	39%	48%	4.0	10.0
4	0.94	$674	$2,562	$3,236	$18	21%	17%	62%	5.0	9.3
5	0.95	$711	$2,525	$3,236	$18	32%	10%	59%	6.7	9.9
6	2.00	$1,575	$1,561	$3,136	$112	50%	5%	45%	9.4	26.2
7	2.35	$1,703	$1,374	$3,076	$171	50%	1%	49%	9.0	20.0

[j] Large differences in the average and median values for PBP are due to outliers in the distribution of results. A limited number of excessively long PBPs produce an average PBP that is very long. Therefore, in these cases, the median PBP is a more representative value to gauge the length of the PBP.

Table 8.11.3 Oil-Fired Water Heaters: LCC and PBP Results

Efficiency Level ID	Energy Factor	Life-Cycle Cost *(2009$)* Average Installed Price	Average Lifetime Operating Cost	Average LCC	Life-Cycle Cost Savings Average Savings *(2009$)*	Households with Net Cost	No Impact	Net Benefit	Payback Period *(years)* Median	Average
Baseline	0.53	$1,974	$6,655	$8,629						
1	0.54	$1,988	$6,530	$8,518	$0	0%	100%	0%	NA	NA
2	0.56	$2,011	$6,295	$8,296	$54	0%	76%	24%	0.6	0.6
3	0.58	$2,026	$6,076	$8,102	$101	0%	76%	24%	0.9	0.9
4	0.60	$2,013	$5,872	$7,885	$203	0%	54%	46%	0.3	0.2
5	0.62	$2,040	$5,681	$7,721	$295	0%	47%	53%	0.5	0.7
6	0.66	$2,180	$5,407	$7,587	$391	2%	33%	65%	2.3	3.3
7	0.68	$2,180	$5,283	$7,463	$495	0%	17%	83%	1.9	2.1

Table 8.11.4 Gas-Fired Instantaneous Water Heaters: LCC and PBP Results

Efficiency Level ID	Energy Factor	Life-Cycle Cost *(2009$)* Average Installed Price	Average Lifetime Operating Cost	Average LCC	Life-Cycle Cost Savings Average Savings *(2009$)*	Households with Net Cost	No Impact	Net Benefit	Payback Period *(years)* Median	Average
Baseline	0.62	$1,779	$4,290	$6,069						
1	0.69	$1,808	$3,890	$5,698	$4	0%	99%	1%	1.2	1.1
2	0.78	$2,091	$3,238	$5,330	$19	0%	96%	4%	6.1	6.1
3	0.80	$2,305	$3,182	$5,486	$11	2%	95%	3%	10.8	25.9
4	0.82	$2,380	$3,125	$5,505	$9	5%	91%	4%	14.8	24.3
5	0.84	$2,952	$3,071	$6,023	-$308	60%	39%	1%	149.6	203.0
6	0.85	$3,053	$3,045	$6,098	-$355	63%	37%	1%	131.0	172.0
7	0.92	$2,896	$2,880	$5,775	-$137	55%	33%	13%	30.4	44.7
8	0.95	$3,097	$2,816	$5,913	-$259	77%	12%	11%	38.7	55.0

8.11.1.3 Range of LCC Savings and PBPs

Figure 8.11.13 through Figure 8.11.16 show the range of LCC savings for the efficiency levels considered for each of the water heater product classes. For each standard level, the top and the bottom of the box indicate the 75th and 25th percentiles, respectively. The bar at the middle of the box indicates the median; 50 percent of the households have LCC savings above this value. The 'whiskers' at the bottom and the top of the box indicate the 5th and 95th percentiles. The small box shows the average LCC savings for each standard level. Figure 8.11.17 through Figure 8.11.20 show the range of PBPs for the four water heater product classes.

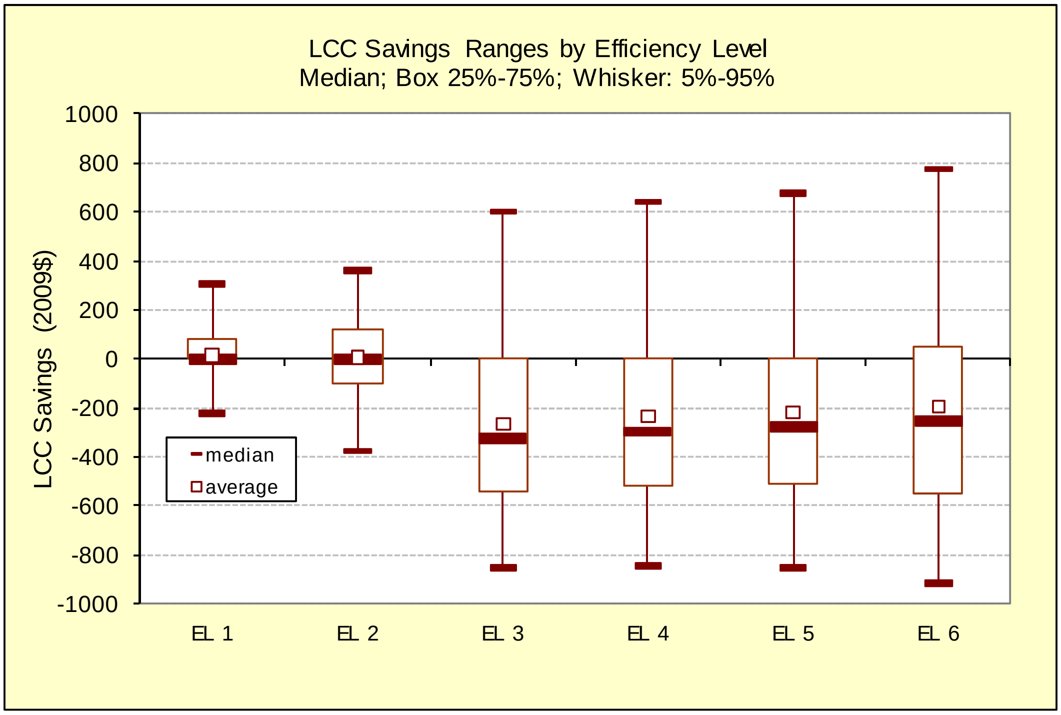

Figure 8.11.13 Range of LCC Savings for Gas-Fired Storage Water Heaters by Efficiency Level

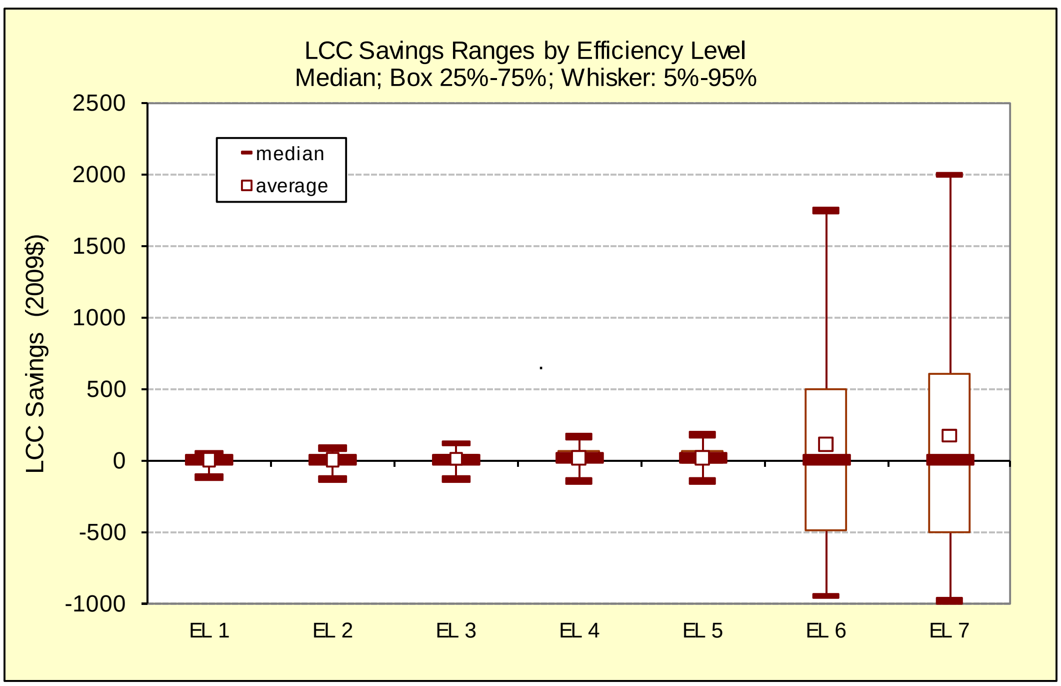

Figure 8.11.14 Range of LCC Savings for Electric Storage Water Heaters by Efficiency Level

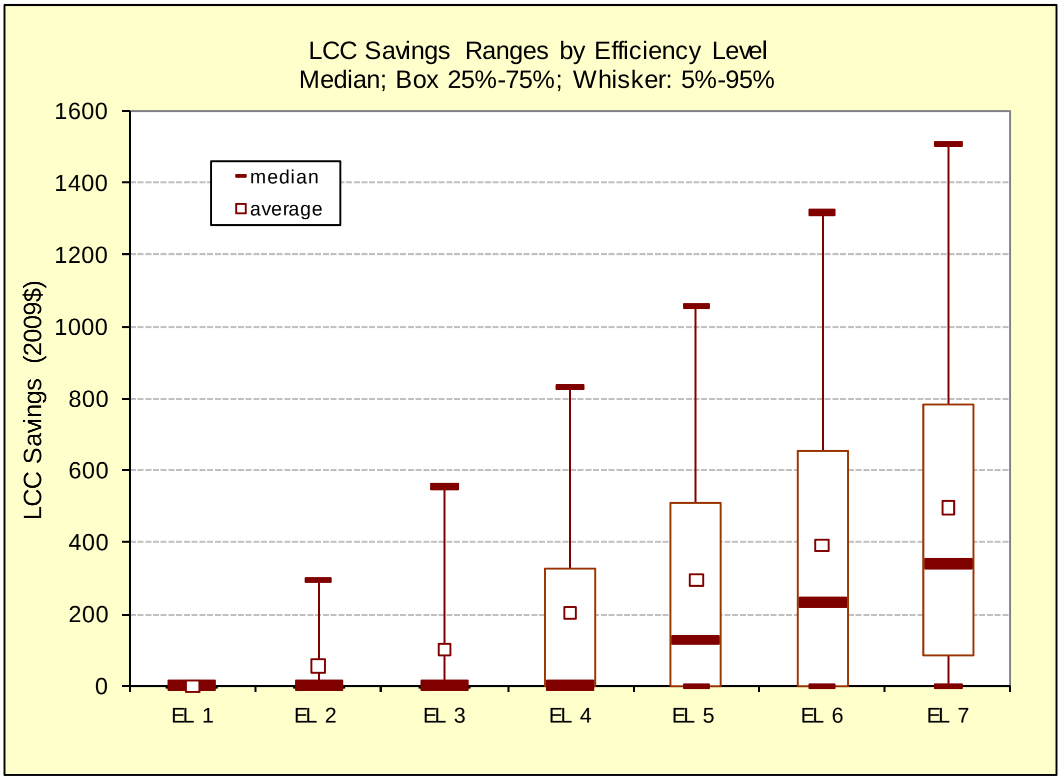

Figure 8.11.15 Range of LCC Savings for Oil-Fired Storage Water Heaters by Efficiency Level

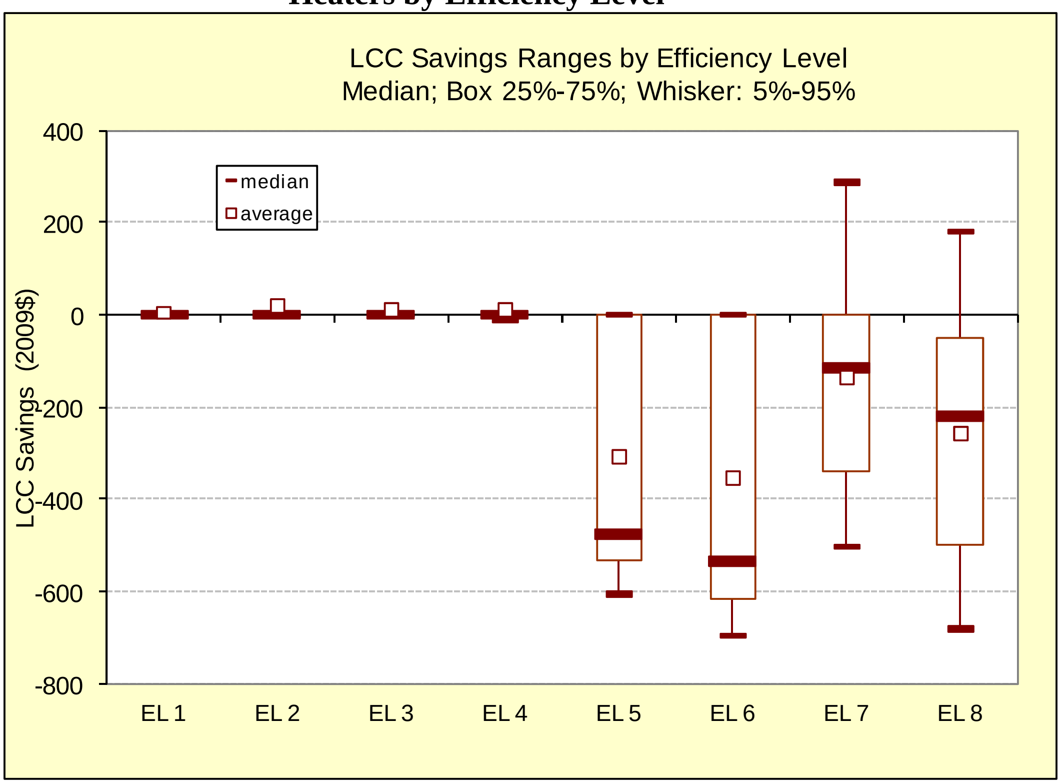

Figure 8.11.16 Range of LCC Savings for Gas-Fired Instantaneous Water Heaters by Efficiency Level

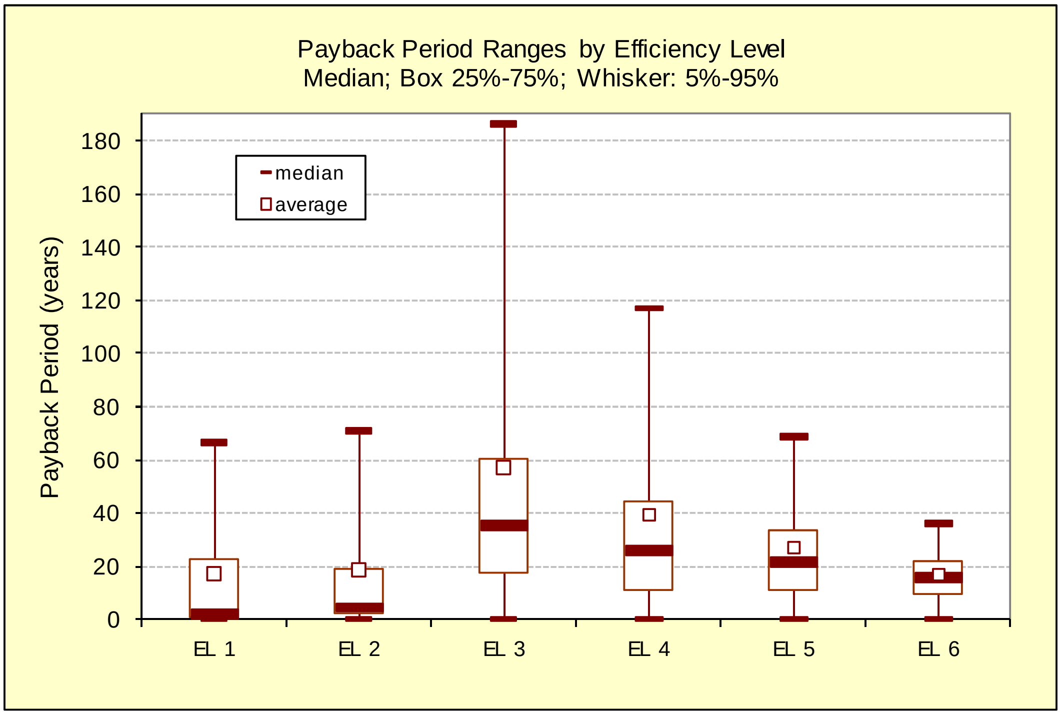

Figure 8.11.17 Range of Payback Periods for Gas-Fired Storage Water Heaters by Efficiency Level

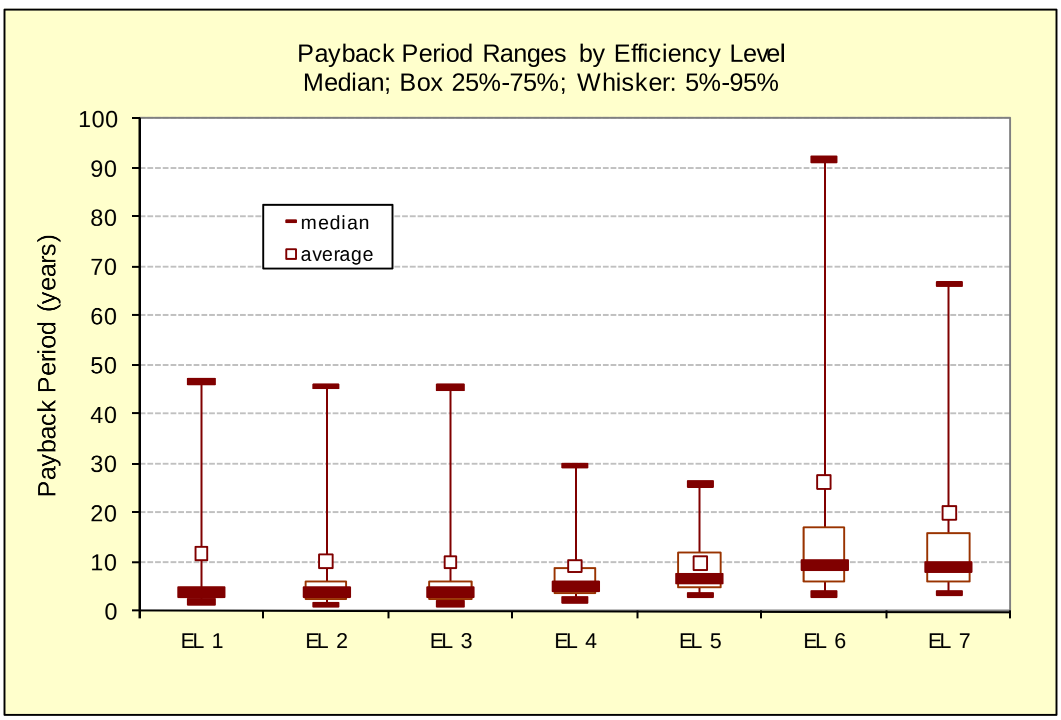

Figure 8.11.18 Range of Payback Periods for Electric Storage Water Heaters by Efficiency Level

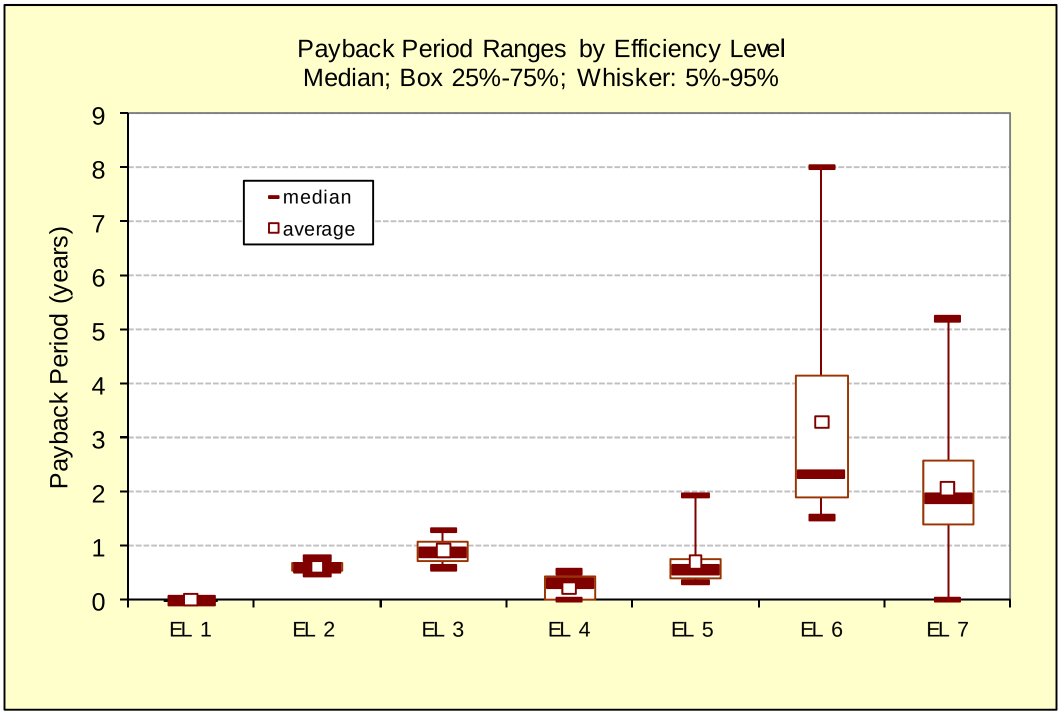

Figure 8.11.19 Range of Payback Periods for Oil-Fired Storage Water Heaters by Efficiency Level

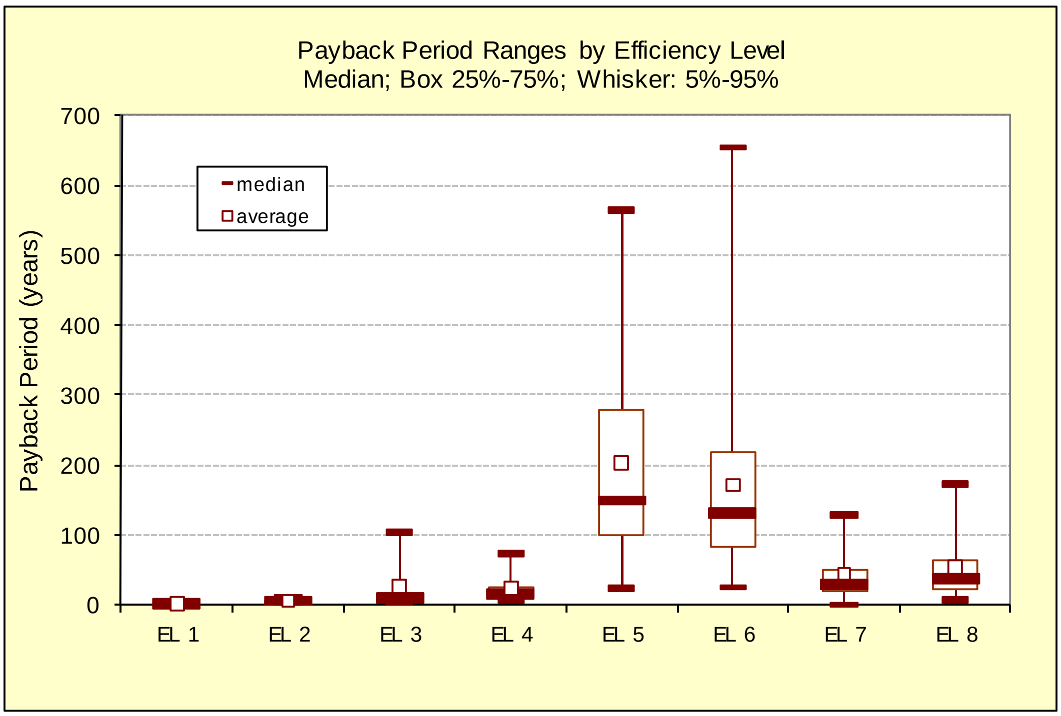

Figure 8.11.20 Range of Payback Periods for Gas-Fired Instantaneous Water Heaters by Efficiency Level

8.11.1.4 Gas-Fired and Electric Storage Water Heaters: Results for TSL 5

As explained in chapter 10, DOE wanted to consider a pairing of efficiency levels that would promote the penetration of advanced technologies into the electric and gas-fired storage water heater markets and potentially save additional energy. Consequently, DOE is pairing an efficiency level that requires heat pump technology for large-volume electric storage water heaters with an efficiency level achievable using electric resistance technology for small-volume electric storage water heaters. In addition, DOE is pairing an efficiency level that requires condensing technology for large-volume gas storage water heaters with an efficiency level that can be achieved in atmospherically-vented gas-fired storage water heaters with increased insulation thickness for small storage volumes.

TSL 5 and TSL 6 includes efficiency levels that require heat pump technology for electric storage water heaters with rated storage volumes at and above 56 gallons, and efficiency levels that require condensing technology for gas-fired storage water heaters with rated storage volumes at and above 56 gallons. Based on its market assessment, DOE estimated approximately 4 percent of gas-fired storage water heater shipments and 11 percent of models would be subject to the large-volume water heater requirements. Similarly, DOE estimated approximately 9 percent of electric storage water heater shipments and 27 percent of models would be subject to the large-volume water heater requirements.

To derive the LCC and PBP results for TSL 5, DOE divided each of the household samples for gas and electric water heaters into two groups, one consisting of households with small-volume water heaters, and the other consisting of households with large-volume water heaters. Using the appropriate inputs for the efficiency level pairs for each product class, DOE calculated results for each of the small- and large-volume subgroups, as described in appendix 8-I. DOE then weighted the subgroup results using the shipments market shares of small- and large-volume water heaters described above. Table 8.11.5 and Table 8.11.6 show the results for each subgroup at the efficiency levels specified in TSL 5, along with the weighted-average total results.

Table 8.11.5 Gas-Fired Storage Water Heaters: LCC and PBP Results for Small and Large-Volume Water Heaters Under TSL 5

Volume Subgroup and Energy Factor	Market Share (%)	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*	
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with Net Cost	Households with No Impact	Households with Net Benefit	Median	Average
Small at 0.62	96.1	$1,164	$2,327	$3,491	$15	25%	33%	38%	2.0	17.2
Large at 0.77	3.9	$2,066	$2,404	$4,470	$77	2%	0%	2%	9.8	10.3
Wtd-avg Total*	100	$1,199	$2,330	$3,528	$18	27%	33%	40%	2.3	16.9

* Weighted by shares of shipments for small and large volume units.

Table 8.11.6 Gas-Fired Storage Water Heaters: LCC and PBP Results for Small and Large-Volume Water Heaters Under TSL 6

Volume Subgroup and Energy Factor	Market Share (%)	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*	
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median	Average
						Net Cost	No Impact	Net Benefit		
Small at 0.63	96.1	$1,238	$2,262	$3,499	$6	32%	21%	44%	4.5	18.6
Large at 0.77	3.9	$2,066	$2,404	$4,470	$77	2%	0%	2%	9.8	10.3
Wtd-avg Total*	100	$1,270	$2,267	$3,537	$9	34%	21%	46%	4.7	18.3

* Weighted by shares of shipments for small and large volume units.

Table 8.11.7 Electric Storage Water Heaters: LCC and PBP Results for Small and Large-Volume Water Heaters Under TSL 5 and TSL 6

Volume Subgroup and Energy Factor	Market Share (%)	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*	
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median	Average
						Net Cost	No Impact	Net Benefit		
Small at 0.95	90.7	$693	$2,440	$3,134	$10	31%	8%	52%	6.9	10.3
Large at 2.00	9.3	$1,703	$2,046	$3,749	$626	2%	1%	6%	6.0	8.5
Wtd-avg Total*	100	$782	$2,406	$3,188	$64	33%	9%	58%	6.8	10.2

* Weighted by shares of shipments for small and large volume units.

8.11.2 Direct Heating Equipment

8.11.2.1 Distributions of Impacts

Figure 8.11.21 through Figure 8.11.25 show the full range of LCCs for the base case for the five direct heating equipment product classes.

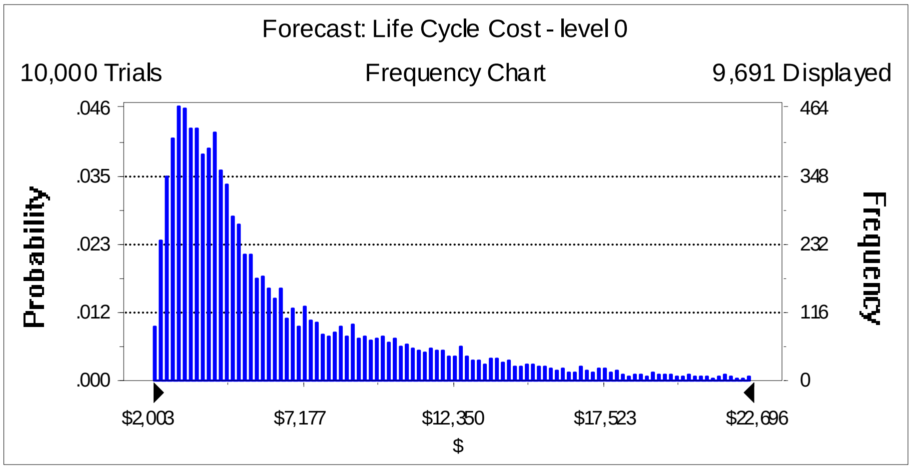

Figure 8.11.21 Gas Wall Fan DHE: Base Case LCC Distribution

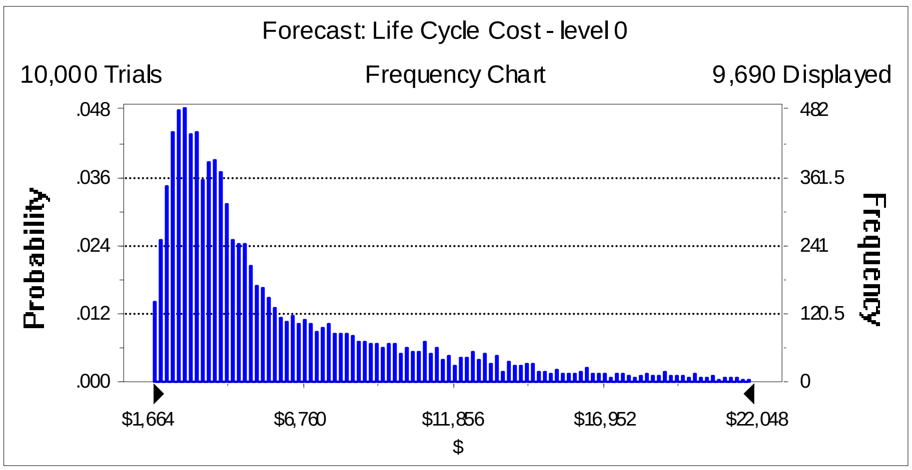

Figure 8.11.22 Gas Wall Gravity DHE: Base Case LCC Distribution

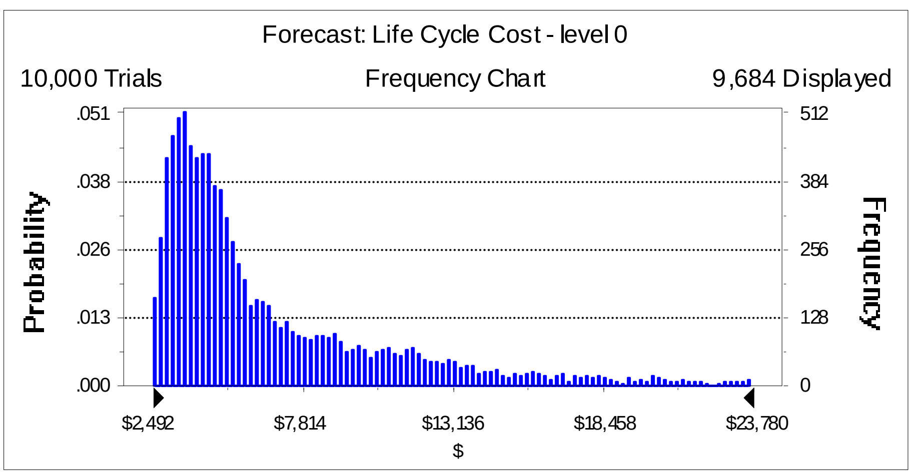

Figure 8.11.23 Gas Floor DHE: Base Case LCC Distribution

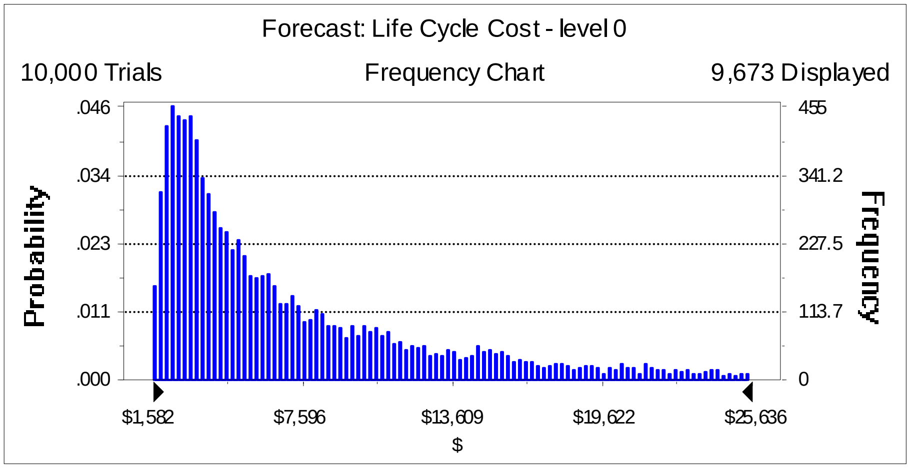

Figure 8.11.24 Gas Room DHE: Base Case LCC Distribution

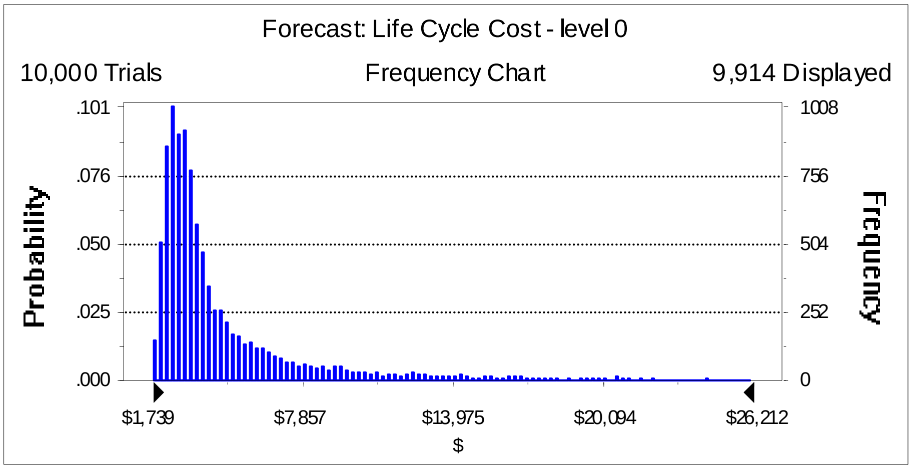

Figure 8.11.25 Gas Hearth DHE: Base Case LCC Distribution

Figure 8.11.26 is an example of a frequency chart showing the distribution of LCC impacts for the case of standard level 3 for gas wall fan DHE. DOE can generate a frequency chart like the one shown in Figure 8.11.26 for every standard level within each product class. Similarly, Figure 8.11.27 through Figure 8.11.30 are examples of frequency charts showing the distribution of LCC impacts for the other direct heating equipment product classes.

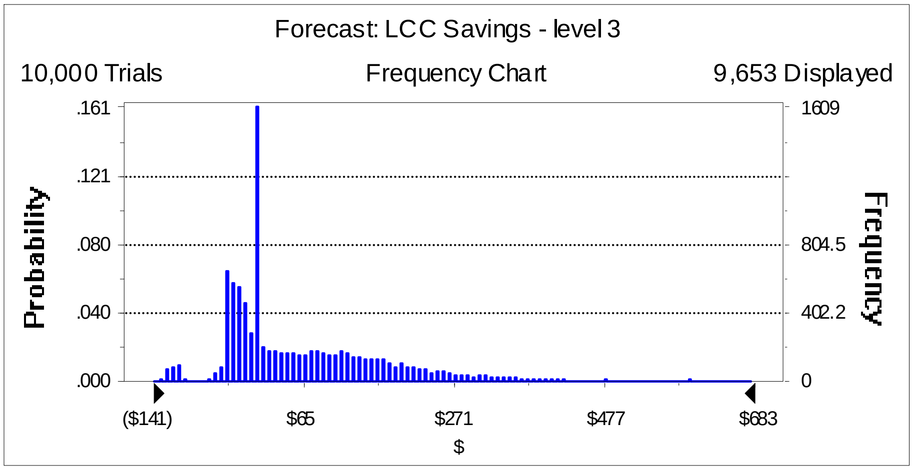

Figure 8.11.26 Gas Wall Fan DHE: Distribution of LCC Impacts for Efficiency Level 3

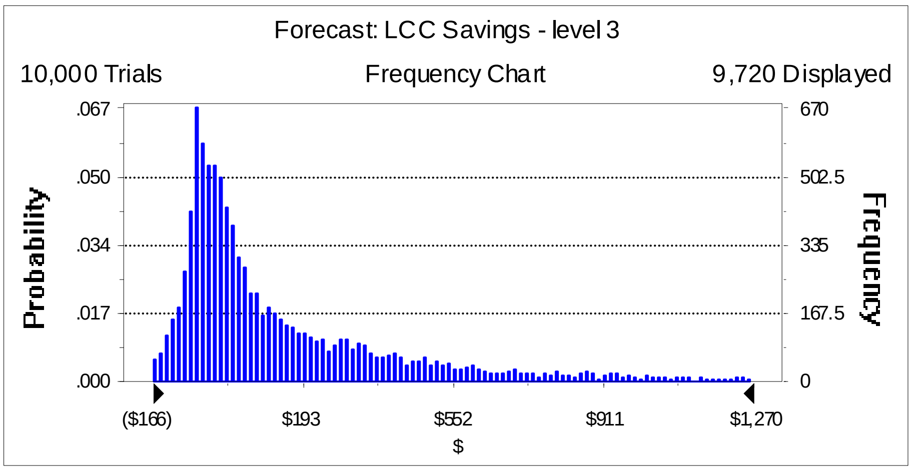

Figure 8.11.27 Gas Wall Gravity DHE: Distribution of LCC Impacts for Efficiency Level 3

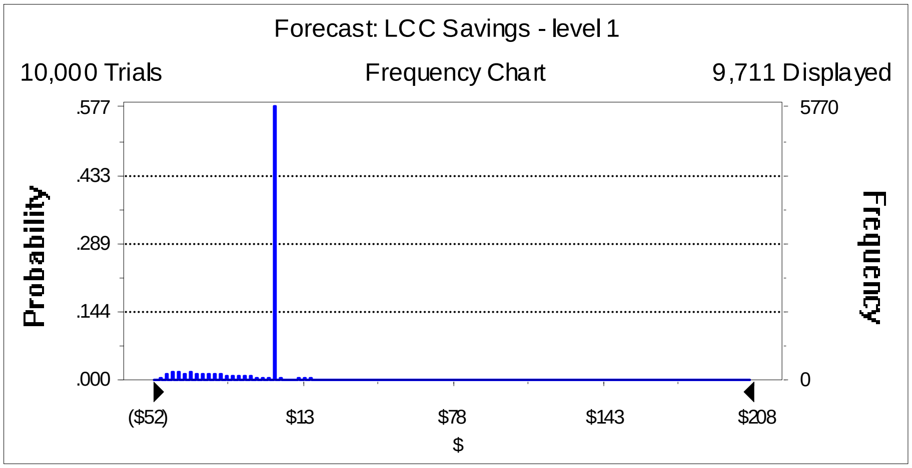

Figure 8.11.28 Gas Floor DHE: Distribution of LCC Impacts for Efficiency Level 1

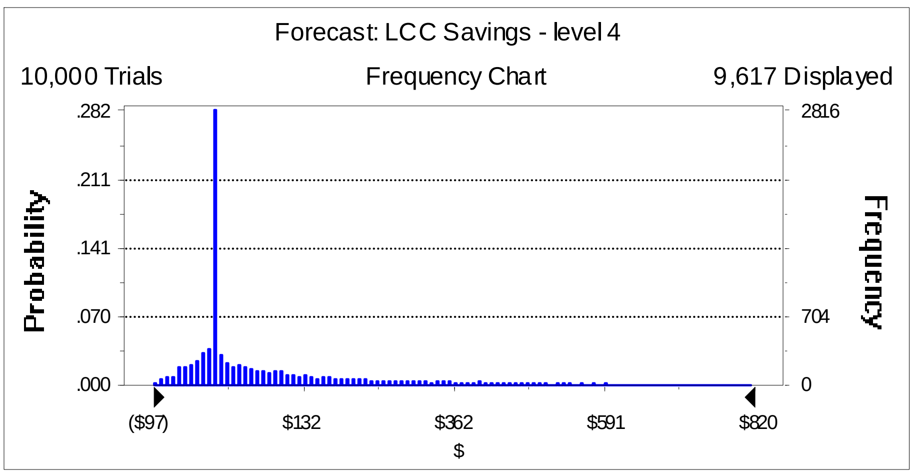

Figure 8.11.29 Gas Room DHE: Distribution of LCC Impacts for Efficiency Level 4

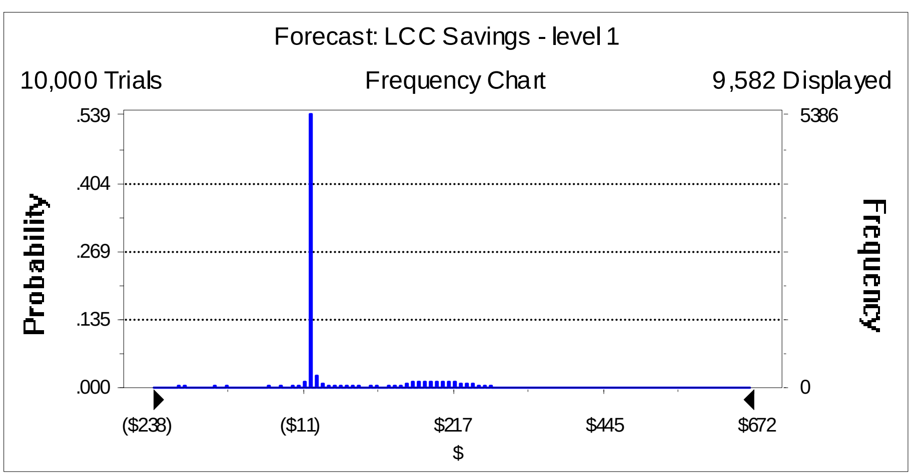

Figure 8.11.30 Gas Hearth DHE: Distribution of LCC Impacts for Efficiency Level 1

Figure 8.11.31 through Figure 8.11.35 are examples of a frequency chart for direct heating equipment products showing the distribution of payback periods for different standard levels. DOE can generate frequency charts like these for every standard level within each product class. The large spike at the left in Figure 8.11.33 and Figure 8.11.34 indicates the percentage of households with gas floor DHE and gas room DHE that are not impacted by an increase in the standard level, i.e., households that already use gas floor DHE and gas room DHE with energy efficiencies equal to or greater than the standard level.

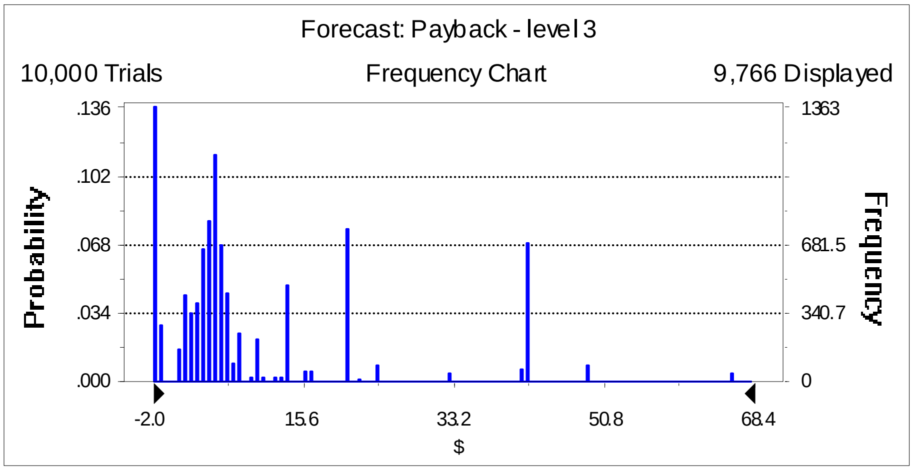

Figure 8.11.31 Gas Wall Fan DHE: Distribution of PBPs for Efficiency Level 3

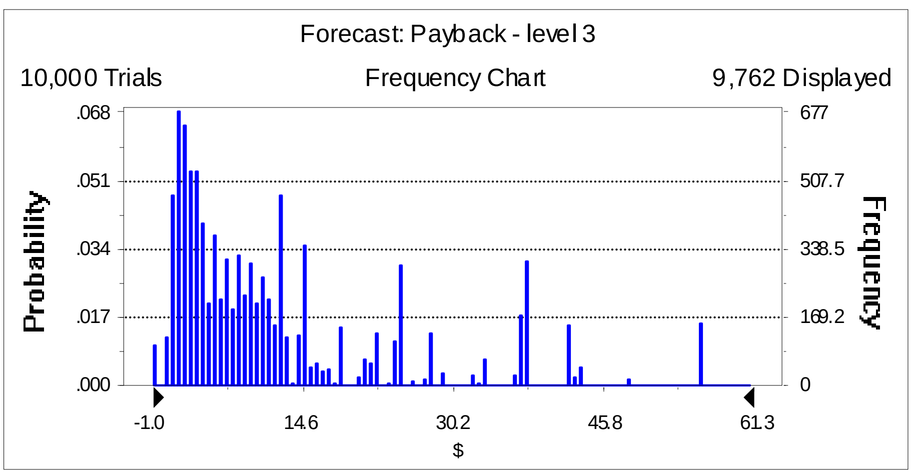

Figure 8.11.32 Gas Wall Gravity DHE: Distribution of PBPs for Efficiency Level 3

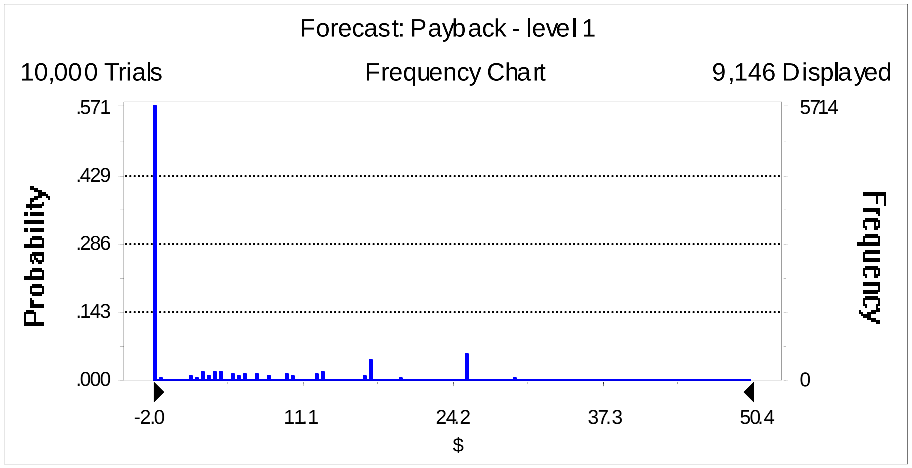

Figure 8.11.33 Gas Floor DHE: Distribution of PBPs for Efficiency Level 1

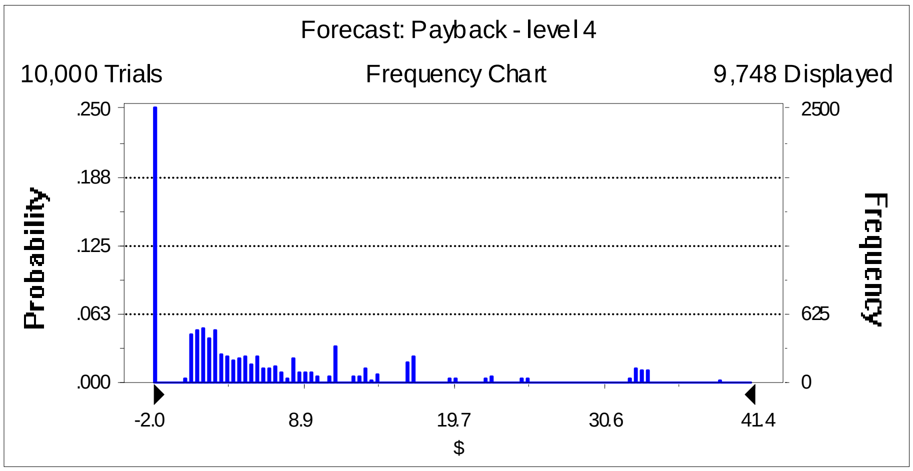

Figure 8.11.34 Gas Room DHE: Distribution of PBPs for Efficiency Level 4

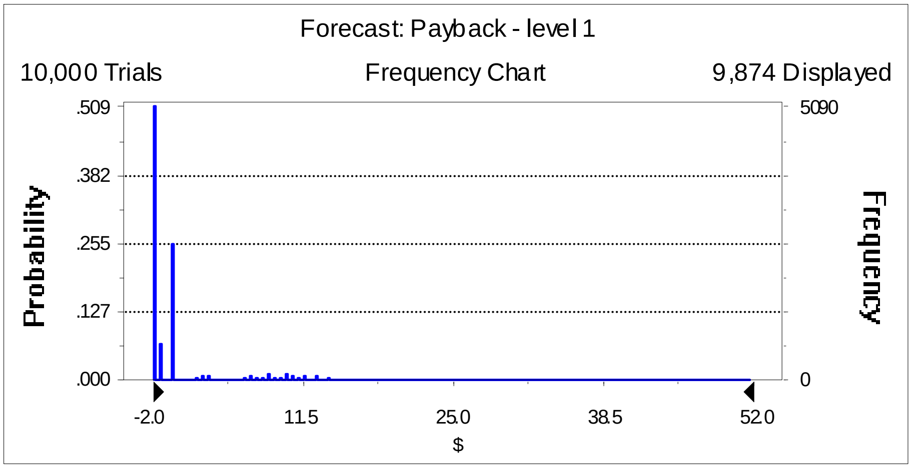

Figure 8.11.35 Gas Hearth DHE: Distribution of PBPs for Efficiency Level 1

8.11.2.2 Summary of LCC and PBP Results

Table 8.11.8 through Table 8.11.12 show the LCC and PBP results for direct heating equipment. As mentioned earlier, for some households, DOE assigned base case products that are more energy efficient than some of the standard levels. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific standard level and the LCC of the baseline products. Similarly with regard to the PBPs shown below, DOE determined the median and average values by excluding the percentage of households not impacted by a standard at a given efficiency level. The values for average lifetime operating cost in the tables are discounted sums of the annual operating costs over the product lifetime.

For gas wall fan DHE, Efficiency Level 3 (77 percent AFUE) has the highest average LCC savings and a median PBP of 5.0 years. For gas wall gravity DHE, Efficiency Level 2 (68 percent AFUE) has the highest average LCC savings and a median PBP of 5.2 years. For gas floor DHE, Efficiency Level 1 (78 percent AFUE) has the highest average LCC savings and a median PBP of 10.7 years. For gas room DHE, Efficiency Level 5 (83 percent AFUE) has the highest average LCC savings and a median PBP of 6.9 years. For gas hearth DHE, Efficiency Level 1 (67 percent AFUE) has the highest average LCC savings and a median PBP of 0.0 years.

Table 8.11.8 Gas Wall Fan DHE: LCC and PBP Results

Efficiency Level ID	AFUE	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*	
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median	Average
						Net Cost	Net Benefit	No Impact		
Baseline	74%	$1,832	$5,544	$7,376						
1	75%	$1,888	$5,282	$7170	$83	0%	60%	40%	2.7	2.7
2	76%	$1,912	$5,218	$7,131	$102	3%	53%	44%	3.2	3.9
3	77%	$1,957	$5,516	$7,114	$114	19%	26%	55%	5.0	9.9
4	80%	$2,200	$4,989	$7,189	$43	53%	7%	40%	12.2	33.7

Table 8.11.9 Gas Wall Gravity DHE: LCC and PBP Results

Efficiency Level ID	AFUE	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*	
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median	Average
						Net Cost	No Impact	Net Benefit		
Baseline	64%	$1,433	$5,500	$6,933						
1	66%	$1,494	$5,354	$6,848	$21	10%	75%	15%	7.5	13.8
2	68%	$1,530	$5,217	$6,747	$72	15%	50%	35%	5.2	11.0
3	69%	$1,609	$5,151	$6,760	$64	33%	37%	30%	11.0	22.5
4	70%	$1,924	$4,956	$6,880	-$56	70%	0%	30%	16.5	18.6

Table 8.11.10 Gas Floor DHE: LCC and PBP Results

Efficiency Level ID	AFUE	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*	
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median	Average
						Net Cost	No Impact	Net Benefit		
Baseline	57%	$2,209	$5,575	$7,785						
1	58%	$2,263	$5,491	$7,755	$13	23%	58%	19%	10.7	16.5

Table 8.11.11 Gas Room DHE: LCC and PBP Results

Efficiency Level ID	AFUE	Life-Cycle Cost *(2009$)* Average Installed Price	Average Lifetime Operating Cost	Average LCC	Life-Cycle Cost Savings Average Savings *(2009$)*	Households with Net Cost	No Impact	Net Benefit	Payback Period *(years)* Median	Average
Baseline	64%	$1,208	$6,242	$7,450						
1	65%	$1,242	$6,157	$7,398	$14	9%	74%	16%	6.6	10.0
2	66%	$1,275	$6,074	$7,349	$26	9%	74%	16%	6.7	11.8
3	67%	$1,291	$5,993	$7,284	$60	12%	50%	38%	4.5	8.3
4	68%	$1,311	$5,915	$7,226	$104	19%	25%	57%	4.8	8.2
5	83%	$1,849	$4,778	$6,628	$702	32%	0%	68%	6.9	8.7

Table 8.11.12 Gas Hearth DHE: LCC and PBP Results

Efficiency Level ID	AFUE	Life-Cycle Cost *(2009$)* Average Installed Price	Average Lifetime Operating Cost	Average LCC	Life-Cycle Cost Savings Average Savings *(2009$)*	Households with Net Cost	No Impact	Net Benefit	Payback Period *(years)* Median	Average
Baseline	64%	$1,603	$3,821	$5,424						
1	67%	$1,685	$3,461	$5,146	$112	3%	61%	37%	0.0	3.1
2	72%	$2,074	$3,250	$5,324	-$28	55%	23%	21%	17.1	47.0
3	93%	$2,867	$2,609	$5,475	-$179	77%	1%	22%	26.8	60.2

8.11.2.3 Range of LCC Savings and PBPs

Figure 8.11.36 through 8.11.40 show the range of LCC savings for the standard levels for the direct heating equipment product class category. For each standard level, the top and the bottom of the box indicate the 75^{th} and 25^{th} percentiles, respectively. The bar at the middle of the box indicates the median; 50 percent of the households have LCC savings above this value. The whiskers at the bottom and the top of the box indicate the 5^{th} and 95^{th} percentiles. The small box shows the average LCC savings for each standard level. Figure 8.11.41 through Figure 8.11.45 show the range of PBPs for the direct heating equipment product class category.

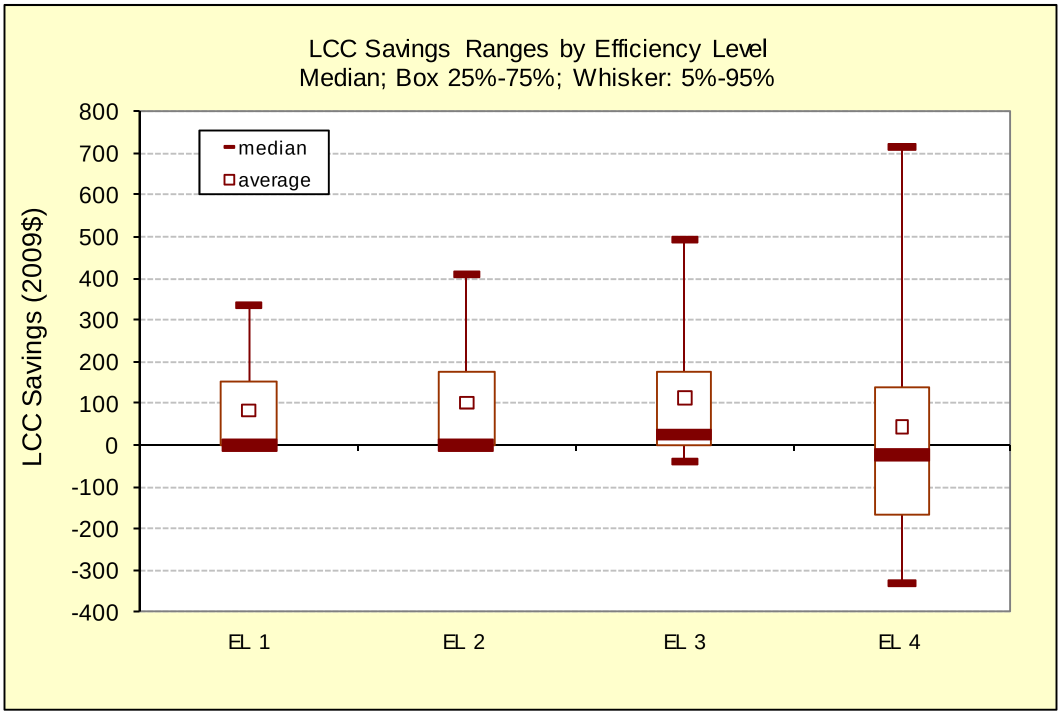

Figure 8.11.36 Range of LCC Savings for Gas Wall Fan DHE

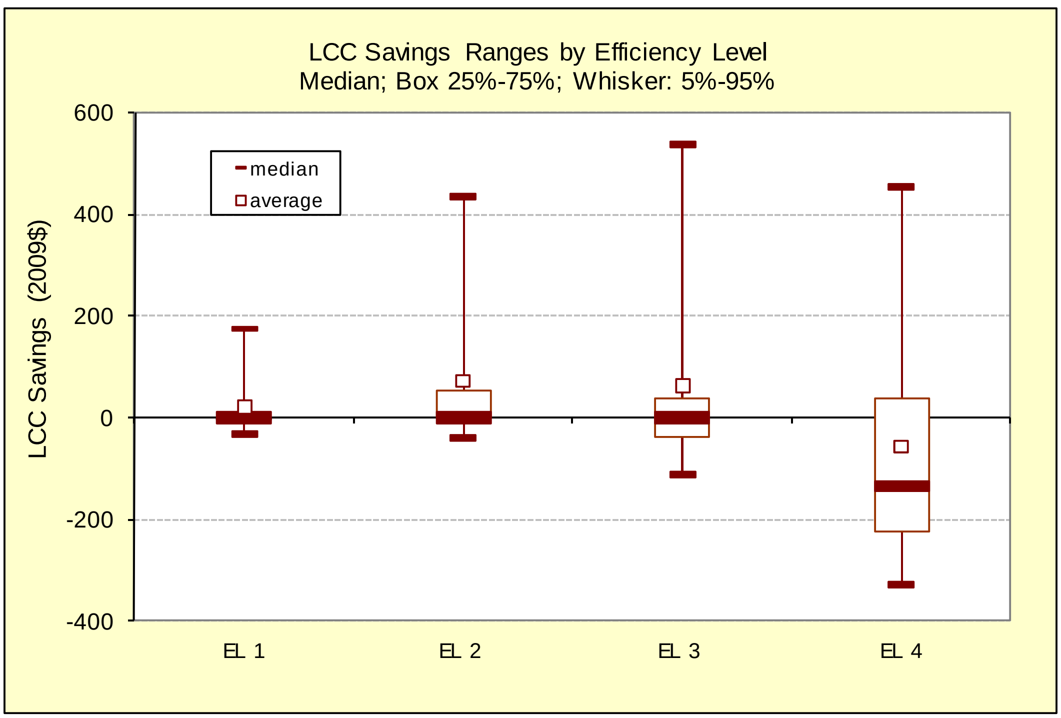

Figure 8.11.37 Range of LCC Savings for Gas Wall Gravity DHE

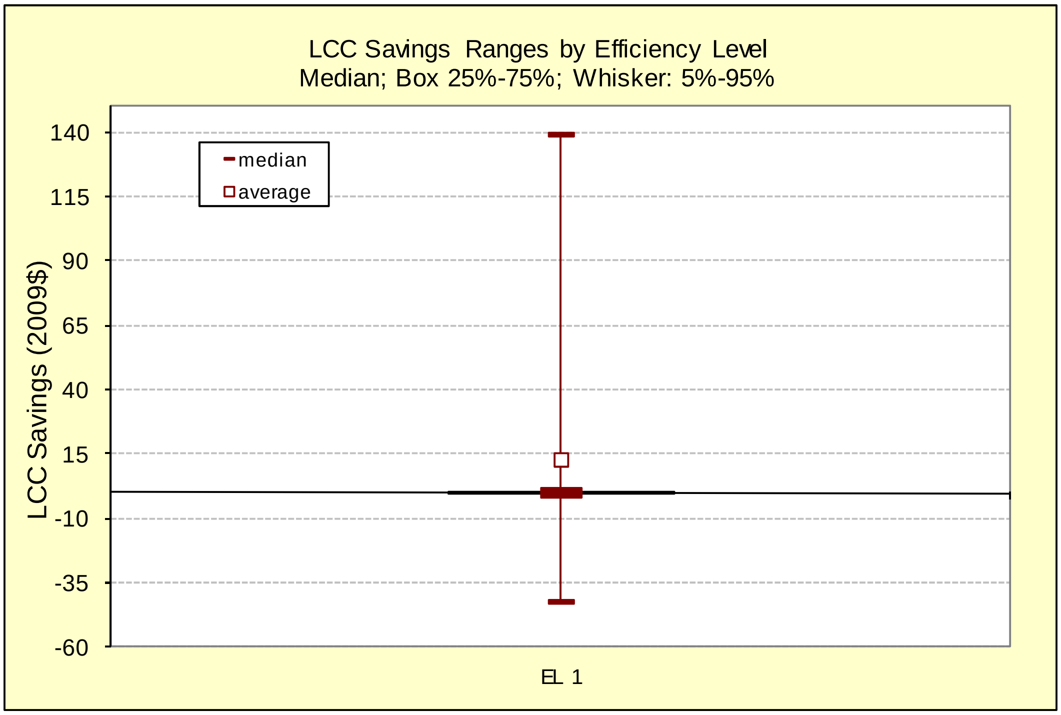

Figure 8.11.38 Range of LCC Savings for Gas Floor DHE

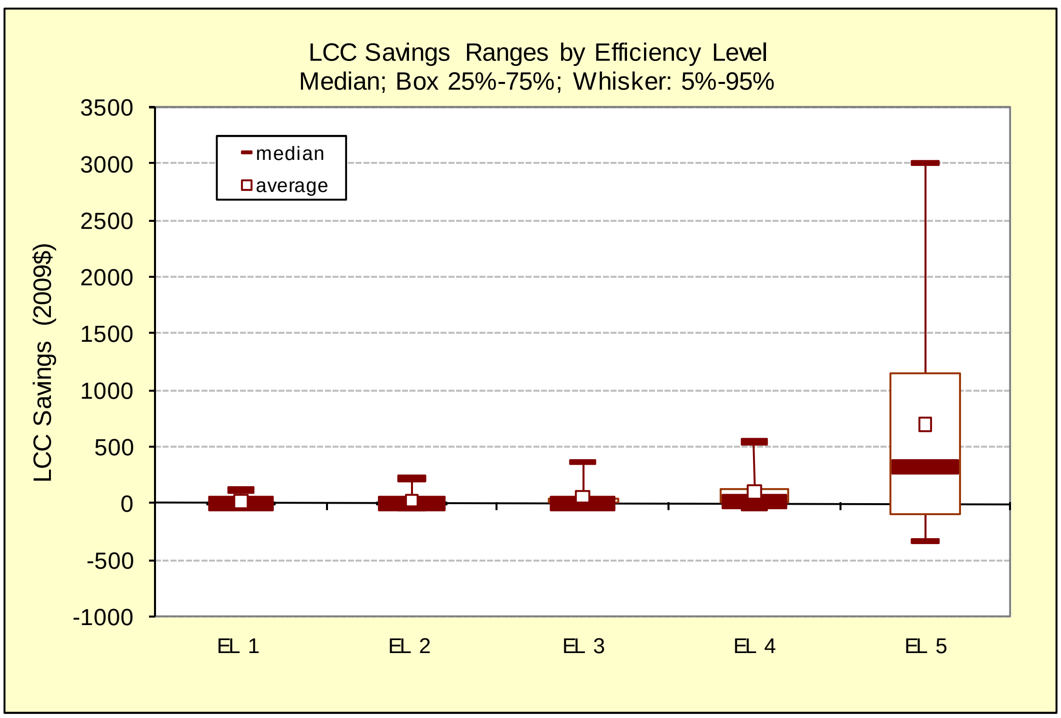

Figure 8.11.39 Range of LCC Savings for Gas Room DHE

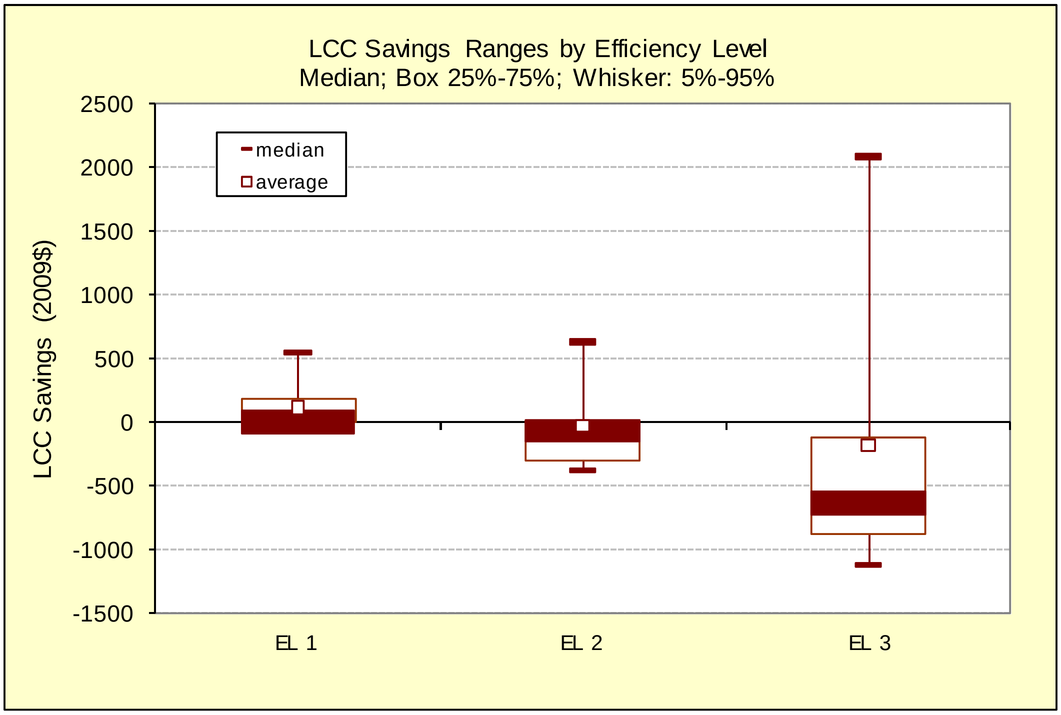

Figure 8.11.40 Range of LCC Savings for Gas Hearth DHE

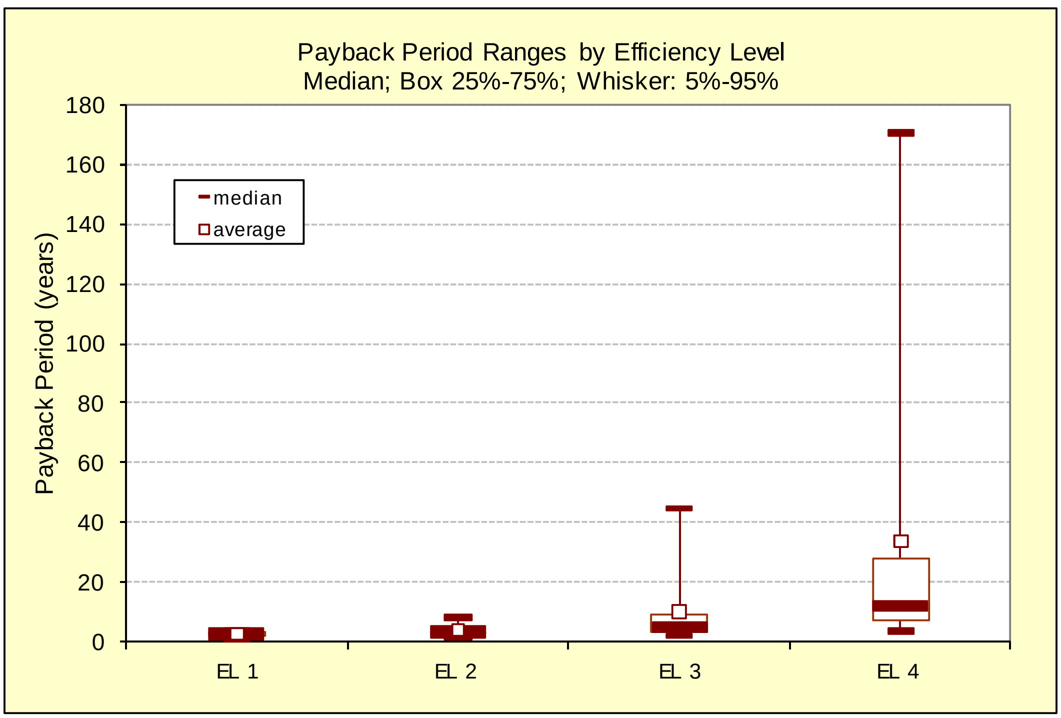

Figure 8.11.41 Range of Payback Periods for Gas Wall Fan DHE

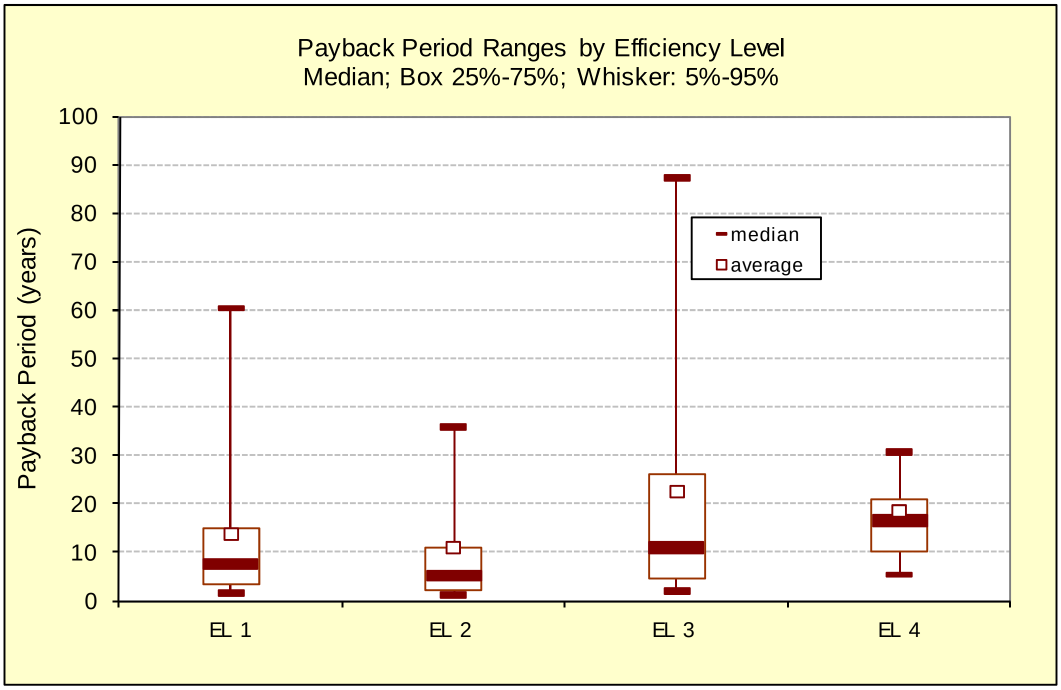

Figure 8.11.42 Range of Payback Periods for Gas Wall Gravity DHE

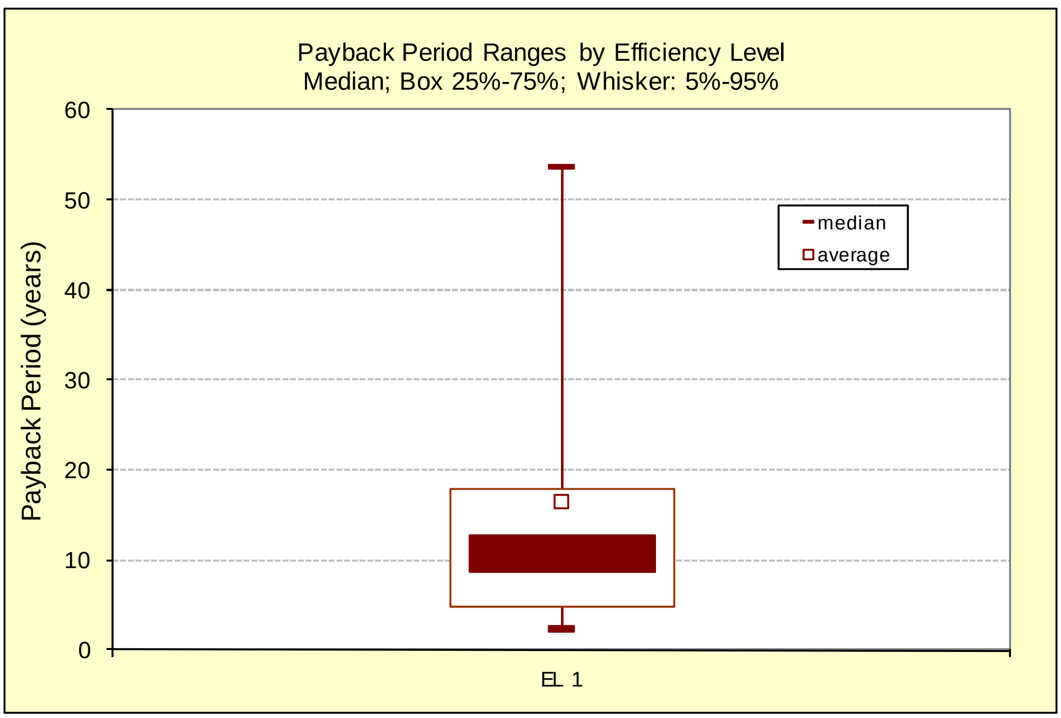

Figure 8.11.43 Range of Payback Periods for Gas Floor DHE

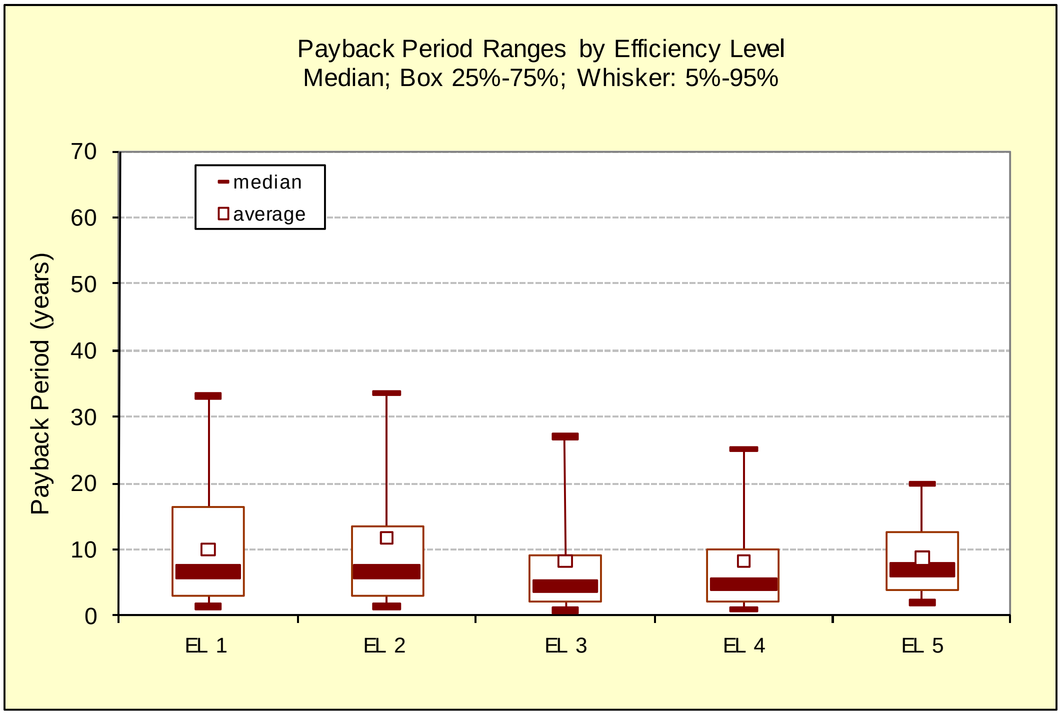

Figure 8.11.44 Range of Payback Periods for Gas Room DHE

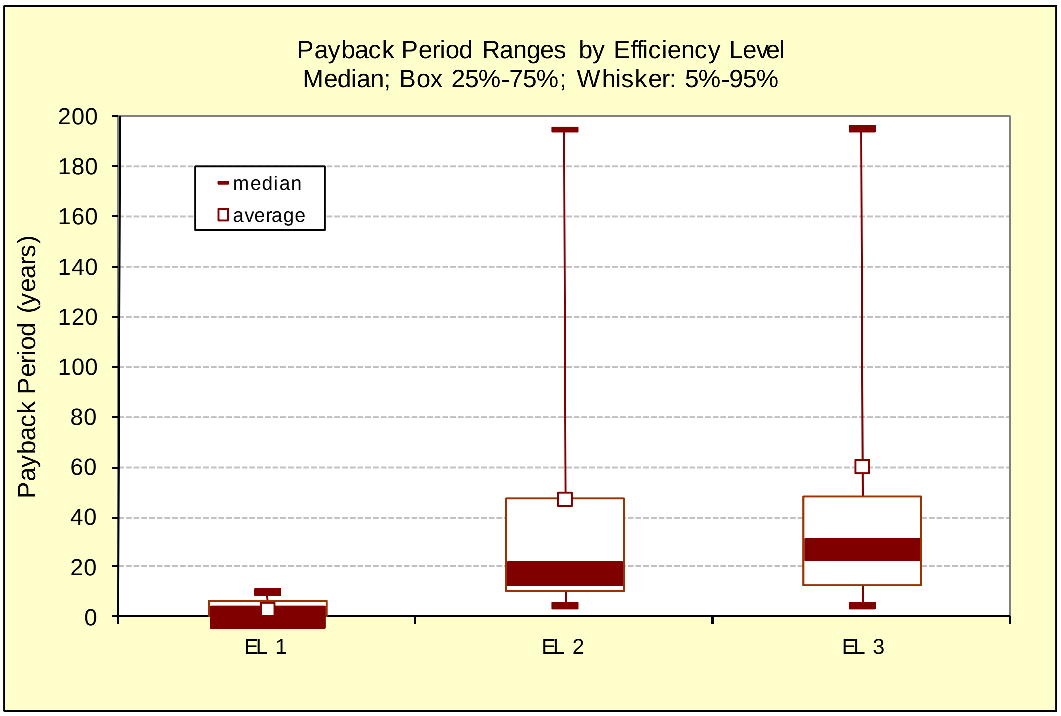

Figure 8.11.45 Range of Payback Periods for Gas Hearth DHE

8.11.3 Gas-Fired Pool Heaters

8.11.3.1 Distributions of Impacts

Figure 8.11.46 shows the full range of LCCs for the base case for gas-fired pool heaters.

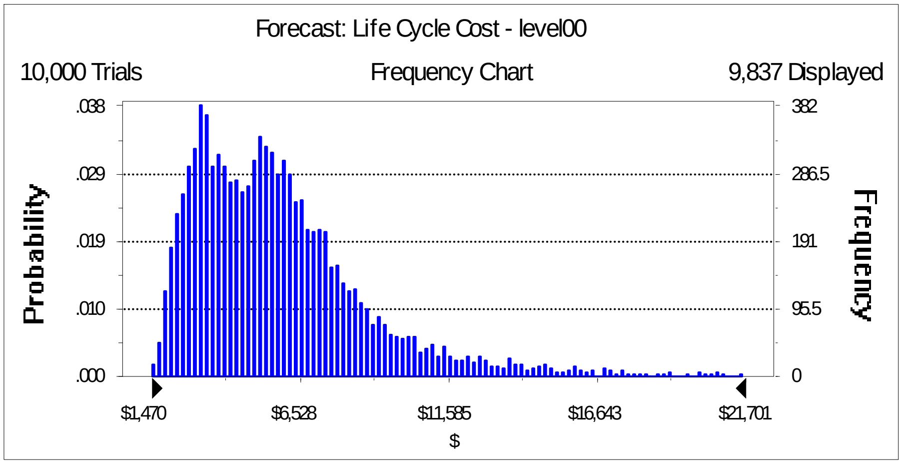

Figure 8.11.46 Gas-Fired Pool Heaters: Base Case LCC Distribution

Figure 8.11.47 is an example of a frequency chart showing the distribution of LCC differences for the case of standard level 5 for gas-fired pool heaters. The large ‘spike’ in Figure 8.11.47 represents the percentage of households that are not impacted by an increase in the standard level, i.e., households that already use pool heaters with energy efficiencies greater than or equal to the standard level. DOE can generate a frequency chart like the one shown in Figure 8.11.47 for every standard level.

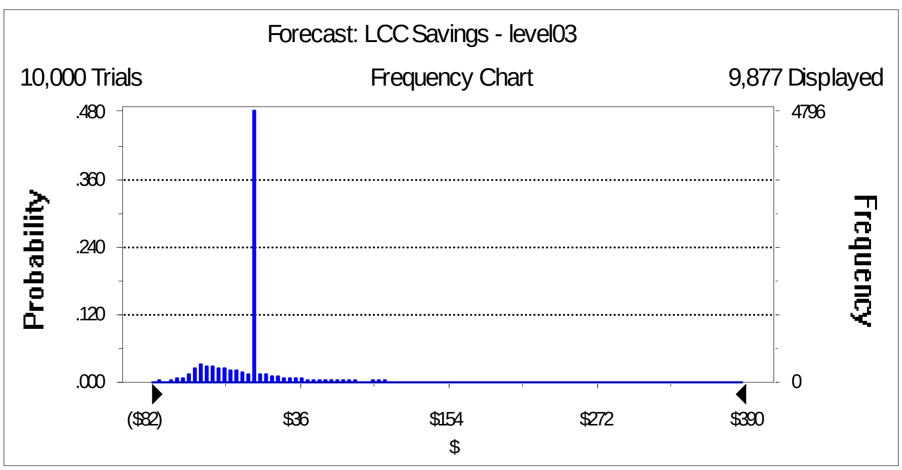

Figure 8.11.47 Gas-Fired Pool Heaters: Distribution of LCC Impacts for Efficiency Level 3

Figure 8.11.48 is an example of a frequency chart showing the distribution of payback periods of Efficiency Level 5 for gas-fired pool heaters. The large spike at the left indicates the percentage of households with pool heaters that are not impacted by an increase in the standard level, i.e., households that purchase pool heaters with energy efficiencies equal to or greater than then standard level. DOE can generate a frequency chart like the one shown in Figure 8.11.48 for every standard level.

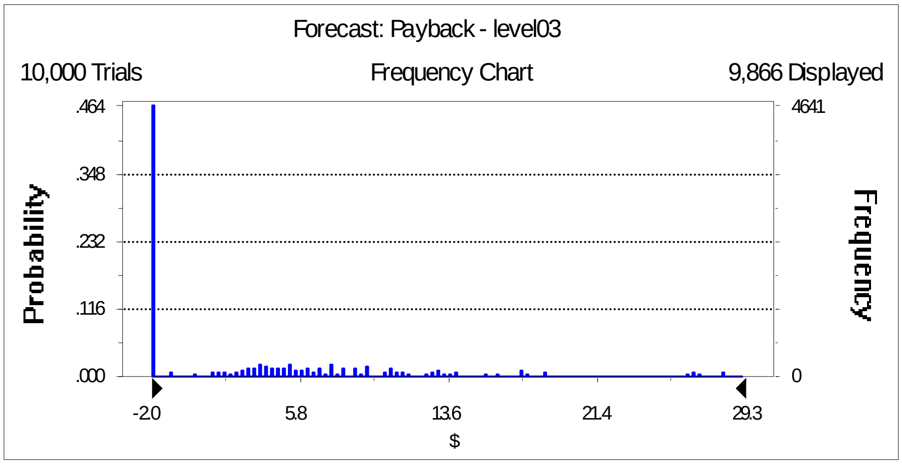

Figure 8.11.48 Gas-Fired Pool Heaters: Distribution of PBPs for Efficiency Level 3

8.11.3.2 Summary of LCC and PBP Results

Table 8.11.13 shows the LCC and PBP results for gas-fired pool heaters. As mentioned earlier, for some households, DOE assigned base case products that are more energy efficient than some of the standard levels. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific standard level and the LCC of the baseline products. Similarly with regard to the PBPs shown below, DOE determined the median and average values by excluding the percentage of households not impacted by a standard at a given efficiency level. The values for average lifetime operating cost in the tables are discounted sums of the annual operating costs over the product lifetime.

For pool heaters, the average LCC savings are highest for Efficiency Level 3, and the median PBP is 8.6 years.

Table 8.11.13 Gas-Fired Pool Heaters: LCC and PBP Results

Efficiency Level ID	Thermal Efficiency	Life-Cycle Cost *(2009$)*			Life-Cycle Cost Savings				Payback Period *(years)*	
		Average Installed Price	Average Lifetime Operating Cost	Average LCC	Average Savings *(2009$)*	Households with			Median	Average
						Net Cost	No Impact	Net Benefit		
Baseline	78%	$3,240	$5,099	$8,339						
1	79%	$3,260	$5,040	$8,300	$1	0%	98%	1%	4.0	5.3
2	81%	$3,285	$4,927	$8,212	$25	5%	72%	23%	2.7	5.4
3	82%	$3,344	$4,873	$8,217	$22	27%	51%	22%	8.6	15.2
4	83%	$3,484	$4,780	$8,264	-$6	60%	23%	17%	18.6	32.3
5	84%	$3,594	$4,728	$8,322	-$52	64%	21%	15%	19.2	39.0
6	86%	$4,146	$4,813	$8,959	-$632	88%	9%	3%	38.1	85.8
7	90%	$5,032	$4,626	$9,658	-$1,322	96%	1%	3%	44.5	99.2
8	95%	$5,283	$4,415	$9,698	-$1,361	95%	1%	4%	33.2	74.1

8.11.3.3 Range of LCC Savings and PBPs

Figure 8.11.49 shows the range of LCC savings for all of the standard levels considered for gas-fired pool heaters. For each standard level, the top and the bottom of the box indicate the 75th and 25th percentiles, respectively. The bar at the middle of the box indicates the median; 50 percent of the households have LCC savings above this value. The 'whiskers' at the bottom and the top of the box indicate the 5th and 95th percentiles. The small box shows the average LCC savings for each standard level. Figure 8.11.50 shows the range of PBPs.

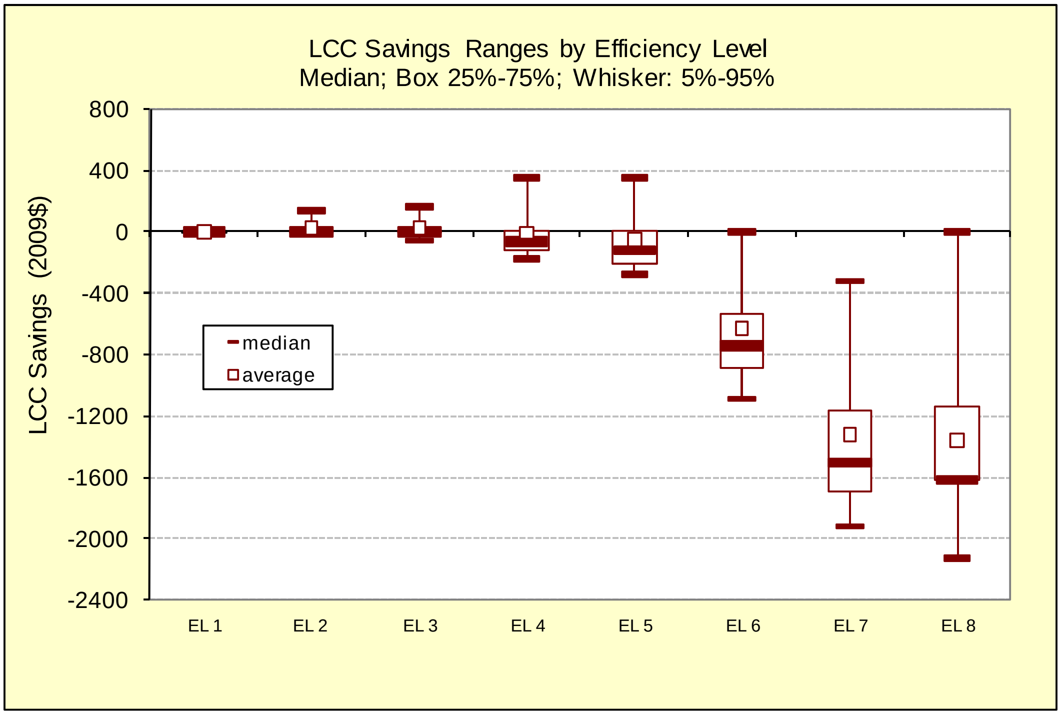

Figure 8.11.49 Range of LCC Savings for Gas-Fired Pool Heaters

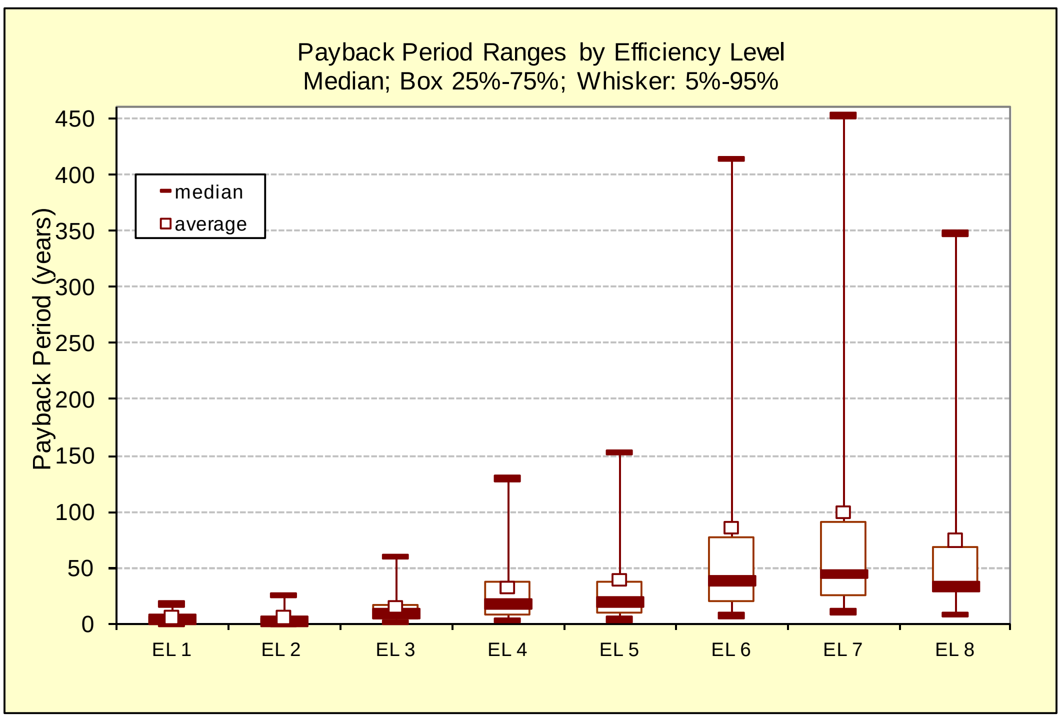

Figure 8.11.50 Range of Payback Periods in Years for Gas-Fired Pool Heaters

8.12 REBUTTABLE PAYBACK PERIOD

DOE presents rebuttable PBPs to establish the rebuttable presumption that an energy conservation standard is economically justified if the additional product costs attributed to the energy conservation standard are less than three times the value of the first-year energy cost savings. (42 U.S.C. §6295 (o)(2)(B)(iii))

The basic equation for rebuttable PBP is the same as that shown in section 8.1.2, Payback Period Inputs. Unlike the analyses described in sections 8.2 and 8.3, the rebuttable PBP is not based on the use of household samples and probability distributions. Rather than distributions, the rebuttable PBP is based on discrete single-point values. For example, while DOE uses regional energy prices in the distributional payback period analysis, it uses only the national average energy price to determine the rebuttable PBP.

Other than the use of single-point values, the most notable difference between the distribution PBP and the rebuttable PBP is the latter's reliance on the DOE test procedure to determine a product's annual energy consumption. Thus, for some of the products (e.g., water heaters) the rebuttable PBPs differ from the average distribution PBP calculated in the LCC and PBP analyses.

8.12.1 Inputs

The following summarizes the single-point values that DOE used in the determination of the rebuttable PBP.

- Manufacturing costs, markups, sales taxes, installation costs, and repair and maintenance costs are all based on the single-point values used in the distributional LCC and PBP analyses.

- Annual energy consumption is based on the DOE test procedure.

- Energy prices are based on national average values for the year that new energy conservation standards are estimated to take effect.

- An average discount rate or lifetime is not required in the rebuttable PBP calculation.

- The effective date of the energy conservation standard is assumed to be 2013 for pool heaters and direct heating equipment, and 2015 for water heaters.

8.12.2 Results

DOE calculated rebuttable PBPs for each standard level relative to the distribution of product energy efficiencies estimated for the base case. In other words, DOE did not determine the rebuttable PBP relative to the baseline energy efficiency level, but relative to the distribution of product energy efficiencies DOE determined for the base case (i.e., the case without new energy conservation standards).

Table 8.12.1 through Table 8.12.3 below only show those efficiency levels for which the calculated PBP is less than three years. For gas-fired and electric storage water heaters, gas wall fan and gravity DHE, gas floor DHE, and gas room DHE there were no payback periods under three years.

Table 8.12.1 Water Heaters: Rebuttable Payback Periods

Product Class	**Energy Factor** *(EF)*	**PBP** *(years)*
Oil-Fired Storage	0.54	0.8
	0.56	0.6
	0.58	0.8
	0.60	0.4
	0.62	0.6
	0.66	1.3
	0.68	1.1
Gas-Fired Instantaneous	0.69	0.9

Table 8.12.2 Direct Heating Equipment: Rebuttable Payback Periods

Product Class	**AFUE**	**PBP** ***(years)***
Gas Hearth DHE	67%	2.5

Table 8.12.3 Pool Heaters: Rebuttable Payback Periods

Product Class	**AFUE**	**PBP** ***(years)***
Gas-fired PH	81%	2.7

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